Missouri Department of Natural Resources

Biological Assessment Report

Missouri River Macroinvertebrate Community and Water Quality Assessment

Missouri American Water Company Jefferson City Plant

Permit Number MO-0004600

August-September 2013

Cole County, Missouri

Prepared for:

Missouri Department of Natural Resources
Division of Environmental Quality
Water Protection Program
Operating Permit Section

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1.0 Introduction

Facilities designed to treat raw water collected from rivers, reservoirs, and groundwater for human consumption must remove harmful and distasteful contaminants to meet minimum state and federal drinking water standards. As part of the treatment process, it is necessary for facilities to periodically clean the various filtering mechanisms by processes known as "backwashing" or "blowdown." Although the two terms are sometimes used interchangeably, there are differences in how the processes are carried out. Backwashing can take the form of forcing water or compressed air in the opposite direction of normal intake, either with or without the use of chemicals to facilitate the cleaning process. Blowdown, by contrast, results from flushing a high volume of water through a given treatment system to remove unwanted deposits. The water resulting from backwashing or blowdown can be recycled and refined into drinking water, sent to a wastewater treatment facility, or discharged into the system from which the raw water came. In Missouri, drinking water treatment facilities located on the Missouri or Mississippi rivers may use this latter alternative.

Missouri American Water Company's **(MAWC)** Jefferson City Plant is located on West Main Street and overlooks the Missouri River from the south bank. The plant's intake is located on the bottom of the river channel and is connected to the plant via a pipeline beneath the river bed. The plant discharges three separate types of effluent, which are generated from the pre-sedimentation, sand filter, and softening processing portions of the plant. Pre-sedimentation is the first stage of treatment. It involves pumping raw river water into a circular tank where sediments drop out of suspension and collect in the bottom of the tank toward the center. The pre-sedimentation effluent is a blowdown event, which purges river sediments that have accumulated in the tank. The sand filter effluent is generated by backwashing, in which a reverse flow of water is forced through the sand filter to eliminate particulate materials that have accumulated there. The final effluent consists partly of lime ($CaCO_3$) slurry from the blowdown of the plant's softening basin. Due to its light color, this effluent is the most visibly notable of the three, and it changes the color of the river at the point of discharge, extending several hundred meters downstream following its release (Figure 1). The three treatment components requiring backwashing or blowdown combine to use approximately 250,000 gallons of water per day at the Jefferson City Plant. Filter backwashing occurs on an as-needed basis, depending on the condition of the filters. Pre-sedimentation and softening basin blowdown each occur at three intervals during the course of a day.

Whether drinking water discharge plumes have a negative effect on the riverine ecosystem is unknown. The State of Missouri is gathering data to determine if permit limits should be set to regulate wastewater released by drinking water treatment facilities. At the request of the Missouri Department of Natural Resources **(MDNR)** Water Protection Program **(WPP)** Operating Permit Section, the Environmental Services Program's **(ESP)** Water Quality Monitoring Section **(WQMS)** conducted an assessment of the water quality and macroinvertebrate community of the Missouri River in the vicinity of the Jefferson City Plant. The plant's current operating permit (Permit Number MO-0004600) includes requirements for measuring flow (millions of gallons per day, **MGD**), tracking the amount of lime used (tons),

and collecting water samples to analyze for total suspended solids **(TSS)** (mg/L), total residual chlorine (**TRC**) (µg/L), pH (standard units), and total recoverable iron (µg/L). This study was designed to assess whether the Jefferson City Plant effluent affects the water chemistry or macroinvertebrate community of the Missouri River.

Figure 1. Jefferson City Drinking Water Plant softening basin blowdown discharge into the Missouri River, September 5, 2013.

2.0 Study Area

The Missouri River at Jefferson City is a 15th order river with a watershed size of 507,500 square miles. As measured approximately 54 river miles upstream at the United States Geological Survey **(USGS)** Boonville, Missouri, gaging station (gage #06909000), the mean annual discharge is roughly 67,000 cubic feet per second **(cfs)**.

Three sampling stations, each of which was approximately 100 feet long, were placed along the right descending bank of the Missouri River upstream of the United States Highway 54/63 bridge (Figure 2). Two sites were positioned downstream of the Jefferson City Plant's discharge pipe, and one located upstream of the outfall was used as a control (Figure 3). The color change in the river resulting from the softening basin effluent was used to gauge the placement of the two downstream stations.

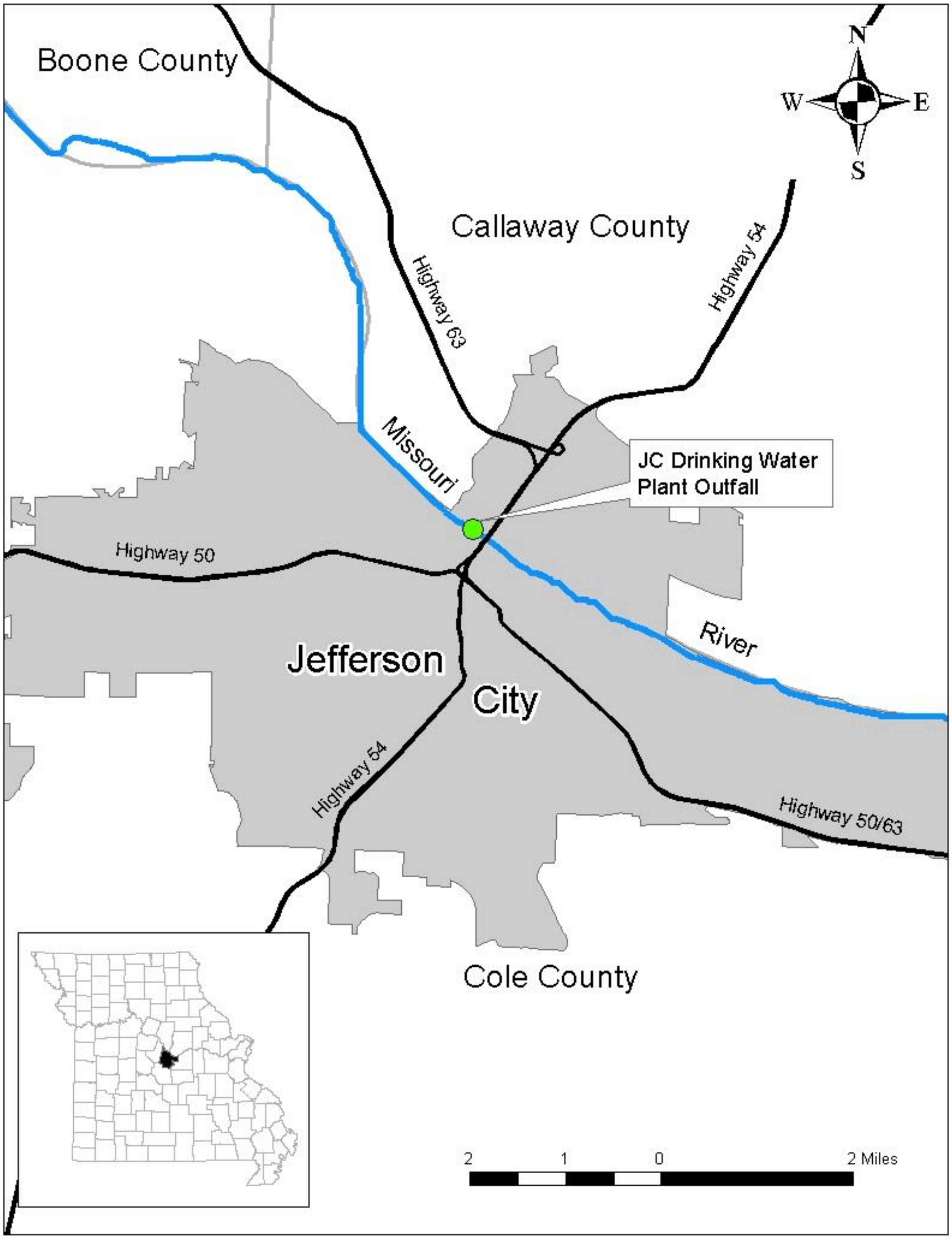

Figure 2. Map of study area.

Figure 3. Aerial photograph of study area showing sample locations and Jefferson City Plant.

3.0 Site Descriptions

All of the following sample sites were in Cole County, Missouri.

The Station 1 (downstream) midpoint was approximately 500 feet downstream of the outfall at SW ¼ Sec. 06, T. 44 N., R. 11 W. Its downstream terminus was located at UTMN 4271229, UTME 571391.

The Station 2 (outfall) midpoint was approximately 50 feet downstream of the outfall at SW ¼ Sec. 06, T. 44 N., R. 11 W. Its downstream terminus was located at UTMN 4271293, UTME 571278.

The Station 3 (upstream control) midpoint was approximately 475 feet upstream of the outfall at SE ¼ Sec. 01, T. 44 N., R. 12 W. Its downstream terminus was located at UTMN 4271369, UTME 571139.

4.0 Objectives

The goal of this study was to determine whether a difference exists in the Missouri River water chemistry or macroinvertebrate community upstream versus downstream from the Jefferson City Plant's outfall. As stated in the study plan (Appendix B), the objectives were to 1) gather water quality data using automated data sondes capable of collecting temperature (°C), dissolved oxygen (mg/L), pH (standard units), turbidity (NTU), and conductivity (µS/cm) both within and upstream of a selected plume; 2) collect *in situ* field water quality measurements (pH, conductivity, dissolved oxygen, temperature, and turbidity) during times when data sondes are maintained and aquatic macroinvertebrate samplers are deployed/retrieved; 3) collect water quality grab samples for laboratory analysis of total dissolved metals, TRC, and TSS; 4) compare the macroinvertebrate community within the Jefferson City Plant's discharge plume with that of the river reach immediately upstream of the outfall; 5) collect macroinvertebrate drift samples using a towed plankton net within the plume and immediately upstream. Due to personnel and time constraints, Objective 5 was not undertaken.

5.0 Null Hypotheses

1) Water quality parameters collected by data sondes will not differ between the test station(s) and the upstream control.

2) *In situ* water chemistry parameters will not differ between the test station(s) and the upstream control.

3) The macroinvertebrate assemblages colonizing multiple-plate samplers will not differ between the test station(s) and the upstream control.

4) The macroinvertebrate assemblages colonizing rock basket samplers will not differ between the test station(s) and the upstream control.

6.0 Methods

Members of the WQMS conducted this study with assistance from Steve Ridenhour of MAWC. Macroinvertebrate samplers were deployed by Ken Lister, Carl Wakefield, and Dave Michaelson. Dave Gullic, Scott Robinett, and Michael Giovanini deployed, maintained, and downloaded data from three data sondes deployed for the study. Weekly water quality grab samples were collected by Brandy Bergthold, Michael Giovanini, Dave Gullic, Ken Lister, Dave Michaelson, Scott Robinett, and Carl Wakefield. Lynn Milberg and Mike Hogan also assisted with overall equipment deployment and field documentation.

6.1 Physicochemical Data Collection and Analysis

Missouri River water chemistry was assessed using grab samples and data sondes. YSI Model 6920 V2 data sondes [YSI Incorporated, Yellow Springs, Ohio 45387 (a subsidiary of Xylem Incorporated)] capable of logging temperature (°C), pH (standard units), conductivity (µS/cm), turbidity (Nephelometric Turbidity Units, **NTU**), and dissolved oxygen (mg/L and percent saturation) were deployed in the water column at each of the sample stations. Sondes were set to collect readings at 2-minute intervals during their deployment. Once weekly, members of the WQMS retrieved each sonde to download data, calibrate the pH sensor, and clean the instrument. The sonde was then returned to its original location.

Water quality grab samples also were collected once weekly during the macroinvertebrate sampler deployment period. Through cooperation with MAWC, WQMS personnel were able to collect grab samples and *in situ* water quality measurements from the Jefferson City Plant outfall for each of the three effluent types as well as from the blending reach in Station 2 immediately following each discharge. For purposes of this report, "blending reach" is defined as the river reach downstream of the Jefferson City Plant outfall in which a visible change in water color resulting from plant effluent was observed. Grab samples were collected at the upstream control station before each discharge. During each sampling trip, personnel from MAWC's Jefferson City Plant would conduct blowdown and backwash events at the request of WQMS staff. In this manner WQMS staff could be in position to collect samples from the outfall (near end-of-pipe) as well as the river as each effluent type occurred. Water quality parameters were measured *in situ* or collected and returned for analyses at the state environmental laboratory. Temperature (^{o}C) (MDNR 2010e), pH (MDNR 2012a), specific conductance (µS/cm) (MDNR 2010c), turbidity (NTU) (MDNR 2010a), TRC (mg/L) (MDNR 2010d), and dissolved oxygen (mg/L) (MDNR 2012c) were measured in the field. Additionally, water samples were collected and analyzed by ESP's Chemical Analysis Section for Dissolved Drinking Water Metals (without mercury) and TSS (mg/L). Samples submitted for dissolved metals analysis were filtered in the field using a 0.45 µm filter prior to preservation. Procedures outlined in *Field Sheet and Chain-of-Custody Record* (MDNR 2010f) and *Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Sampling Considerations* (MDNR 2011) were followed when collecting water quality samples.

River velocity was measured at the surface at each station during the study using a Marsh-McBirney Flo-Mate™ Model 2000 flow meter.

Physicochemical water quality grab sample data were summarized and presented in tabular form for comparison among stations and for each of the discharges. Water quality parameters collected by the three data sondes were presented graphically due to the volume of data points (>27,500 sample events for each sonde) generated during the time of deployment. River stage was measured in feet during the study using USGS gage #06910450 at Jefferson City, Missouri.

6.2 Macroinvertebrate Collection and Analyses

Two types of artificial substrate macroinvertebrate sampling devices were manufactured by WQMS staff and deployed for 32 days from August 8 to September 9, 2013, at the three Missouri River sample stations. The first device was a multiple-plate artificial substrate sampler similar to the design by Hester and Dendy (1962), which was used to quantitatively measure macroinvertebrate community attributes in the water column. For this study a modification of the original Hester-Dendy design as described by DeShon (1995) was used. DeShon's (1995) modified Hester-Dendy units consist of eight 3-inch diameter Masonite plates on a 3-inch long 1/4-inch diameter eyebolt. For each sampler, there are three single spacings, three double spacings, and one triple space between the plates [i.e., 1/8" between 3 plate pairs, 1/4" (3 plates), and 3/8" (1 plate)]. The design was further modified by constructing the plates of 3-inch by 3-inch square plates, rather than 3-inch diameter circular plates (Figure 4). Hester-Dendy samplers were deployed as part of an array that consisted of: 1) an anchor; 2) a PVC tube with 3 Hester-Dendy units attached; and 3) two floating marker buoys (Figure 5). A total of five Hester-Dendy arrays were evenly spaced at 20 foot intervals at each sample site and deployed approximately 25 feet from the water's edge. The colonizable surface area for each three Hester-Dendy sampler array (each array is considered a replicate sample) was approximately three square feet. One-half-inch diameter braided nylon rope secured the anchor of each array either to trees, rebar, or limestone rip rap along the river bank. Of the 15 Hester-Dendy arrays deployed for this study, two were lost at the control site.

The second type of macroinvertebrate sampling device was a series of rock baskets constructed of high density polyethylene turf reinforcement mesh with 1/2-inch by 3/4-inch openings cut into 8-inch wide by 11-inch long rectangles. A set weight of 1-inch diameter crushed limestone gravel was sandwiched between two pieces of mesh, the margin of which was secured with braided nylon mason's twine (Figure 6). Three rock baskets were deployed at each station at evenly spaced intervals to assess the macroinvertebrate community inhabiting the river bottom. Each rock basket was secured to the river bank using methods similar to those used for the Hester-Dendy samplers.

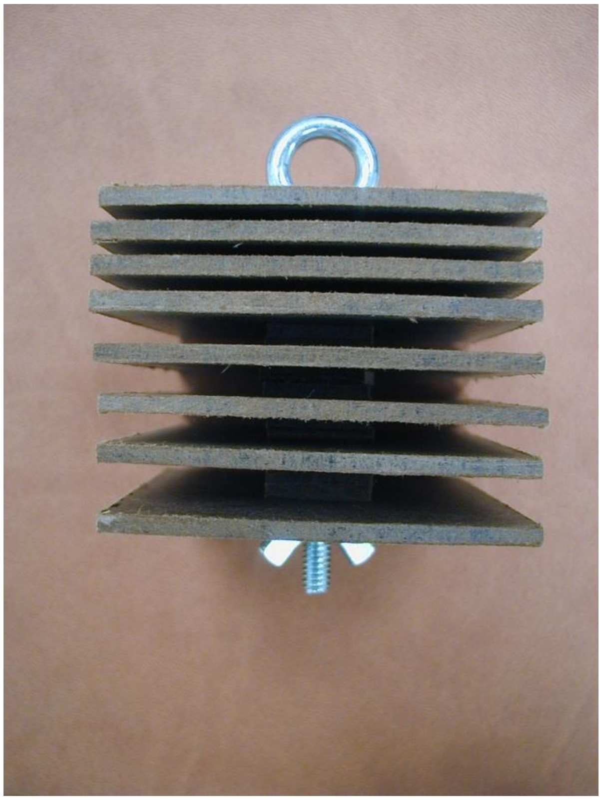

Figure 4. 8-plate Hester-Dendy sampler.

Figure 5. Hester-Dendy sample array.

Figure 6. Rock basket macroinvertebrate sampler.

At the end of the deployment period, a three-person team retrieved the Hester-Dendy arrays and rock baskets. Each bank line was untied and used to pull the array or rock basket from the river bottom. As the sampler approached the water surface, one person placed a bottom aquatic kick net with 500 µm mesh beneath and downstream of the sampler to capture macroinvertebrates that might become dislodged. Hester-Dendy samplers were detached from the array and placed in labeled plastic bags. Organisms captured in the kick net were added to the bag. Plastic bags were then stored in a cooler on ice until the samplers could be processed in the laboratory. Rock baskets were treated similarly, except that each individual rock basket was stored in its own plastic bag.

Once in the laboratory, samplers were removed from the plastic bags and placed in 23-inch x 16-inch x 6-inch plastic storage totes where they were disassembled, immersed in water, and gently scrubbed free of organisms. Rinse water was poured through a $\leq$500 µm sieve. The resulting mix of organisms and debris was placed in 1 L plastic jars, and the sample was preserved in a 10 percent buffered formalin solution.

The decision was made *a priori* to randomly subsample 25 percent of each sample. Due to laboratory error, however, 50 percent of one sample was processed. The numbers generated from this sample were adjusted by dividing the number in half prior to statistical analysis. Laboratory processing was consistent with the *Semi-Quantitative Macroinvertebrate Stream Bioassessment Project Procedure* (**SMSBPP,** MDNR 2012d). Individuals were identified to standard taxonomic levels (MDNR 2010h) and enumerated.

Multiple-plate and rock basket samplers allow for the quantitative analysis of macroinvertebrate data. Statistical analysis of macroinvertebrate density, taxa richness **(TR)**, Ephemeroptera/Plecoptera/Trichoptera Taxa **(EPTT)**, Biotic Index **(BI)**, and Shannon Diversity Index **(SDI)** were conducted using SigmaStat version 3.5 (Systat Software Inc. 2006). Below is a summary of the biological metrics used in assessment of the macroinvertebrate community:

- <u>TR</u>
  This metric reflects the health of the community through a measurement of the number of taxa present. In general, the total number of taxa increases with improving water quality, habitat diversity, and habitat suitability. TR is calculated by counting all taxa from the subsampling effort.

- <u>Total Number of Taxa within the Taxonomic Orders Ephemeroptera, Plecoptera, and Trichoptera</u>
  This value summarizes TR within the insect taxonomic orders that are generally considered to be pollution sensitive. The EPTT index generally increases with higher water quality.

- <u>BI</u>
  This value is a means of describing organic pollution tolerance of individual taxa within the macroinvertebrate communities expressed as a single value between 0 and 10, with 0 being the most sensitive and 10 being the most tolerant.

- SDI
  This index is a measure of community composition that takes into account both richness and evenness. It is assumed that a more diverse community is a more healthy community. Diversity increases as the number of taxa increases and as the distribution of individuals among those taxa is more evenly distributed.

Statistical results are presented in Tables 8 and 9. Macroinvertebrate data used in statistical analysis are presented in Appendix C, and analysis results sheets are presented in Appendix D. When data passed a normality test, one-way Analysis of Variance (**ANOVA**) was used to test for statistical differences (p<0.05). For cases in which data did not pass a normality test, a Kruskal-Wallis One-Way ANOVA on Ranks was used. To determine where individual differences among stations occurred, a pairwise multiple comparison procedure was used such as the Holm-Sidak Method or the Tukey Test. Results were compiled in table format in the report and the statistical datasheets are included as appendices.

When comparing macroinvertebrate density among stations using Hester-Dendy data, calculations had to take into account laboratory subsampling and the fact that each sample was a composite of three Hester-Dendy samplers. The total number from the subsample was first multiplied by four (to account for the 25 percent subsample) and then divided by three to account for the three square feet of surface area per array. Density measures were statistically analyzed for individuals, TR, and EPTT.

The Quantitative Similarity Index (**QSI**) also was calculated to compare the macroinvertebrate community composition among stations. The QSI assesses two communities by taxonomically comparing the presence and absence of macroinvertebrate taxa as well as their relative abundance (Shackleford 1988). This index can be used to assess a system's degree of impairment by establishing QSI threshold values or ranges when comparing test samples with controls. Shackleford (1988) developed scoring criteria in which a QSI greater than 65 percent indicates no impairment. Additional ranges below the 65 percent threshold include minimal impairment (QSI=56-65 percent), substantial impairment (QSI=45-55 percent), and excessive impairment (QSI<45 percent).

6.3 Quality Assurance/Quality Control (QA/QC)

6.3.1 Field Meters

All field meters used to collect water quality parameters were maintained in accordance with the Standard Operating Procedure MDNR-ESP-213, *Quality Control Procedures for Checking Water Quality Field Instruments* (MDNR 2010g).

6.3.2 Data Sondes

Data sondes were maintained and calibrated in accordance with the manufacturer's instructions as well as MDNR-ESP-104, *Continuous or Long-Term Monitoring of Water Quality using a Dissolved Oxygen, Specific Conductivity, pH, Turbidity, Rhodamine Dye, and Temperature Data Logger* (MDNR 2010b). Water quality information collected by the data sondes was scrutinized

prior to being included in this report. If a data point or series of data points were clearly erroneous (due to equipment "drift," biological fouling, or unknown cause), they were eliminated and not included in the graphical representations.

6.3.3 Biological Samples

Steps to assure accuracy of organism removal from sample debris were performed consistent with those methods found in the SMSBPP document (MDNR 2012d).

6.3.4 Biological Data Entry

All macroinvertebrate data were entered into the WQMS macroinvertebrate database consistent with the Standard Operating Procedure MDNR-ESP-214, *Quality Control Procedures for Data Processing* (MDNR 2012b).

7.0 Results

7.1 Physicochemical Data

7.1.1 Missouri River Gaging Station Data

Storms higher in the watershed resulted in the Missouri River stage being slightly elevated on August 8, 2013, when the macroinvertebrate samplers were deployed (Table 1). During the remainder of the deployment period, however, flows were relatively stable.

Table 1. Missouri River USGS Gage Height at Jefferson City, Missouri

Date	Gage height (ft.)
8 August 2013*	11.57
15 August 2013†	6.43
22 August 2013†	7.32
29 August 2013†	5.17
5 September 2013†	5.95
9 September 2013**	5.81

*Hester-Dendy macroinvertebrate samplers deployed
†surface water and outfall sample collection dates
**Hester-Dendy macroinvertebrate samplers retrieved

7.1.2 *In situ* Water Quality Field Parameter Analysis

Water quality results for samples collected *in situ* from the outfall, the upstream control, and the blending reach downstream of the outfall for each effluent type are presented in Tables 2-4. Results are presented separately for each effluent type.

7.1.2.1 Pre-Sedimentation Blowdown

Although several pre-sedimentation effluent water quality field parameters were different compared to the upstream control, readings observed in the blending reach of the Missouri River were variable (Table 2). Pre-sedimentation effluent had turbidity levels that exceeded the instrument's upper limit of 1000 NTU for each of the four sample dates. The effect downstream

varied from no difference in the August 22, 2013, sample to an increase of roughly 40 NTU in the August 15 sample. With the exception of the August 29 effluent sample, dissolved oxygen was higher in the effluent sample than the upstream control, but the difference in the blending reach was negligible. Likewise, pH was slightly higher in the effluent sample than the upstream control, but pH readings in the blending reach either were unchanged or no more than 0.07 units higher than the control. Pre-sedimentation effluent conductivity was 5 to 37 µS/cm lower than the control, but no changes were observed in the blending reach. TRC was variable among sample dates. On August 22, 2013, the effluent TRC concentration was more than 10 times higher than the upstream control, but TRC was not detected in the August 29 sample. TRC in the blending reach, however, was nearly the same as the control for all samples. Blending reach TRC was not analyzed on August 29. Temperature readings among the effluent, blending reach, and control station were similar.

7.1.2.2 Sand Filter Backwash

Of the three effluent types, only the sand filter effluent samples did not exceed the turbidity meter's 1000 NTU upper limit (Table 3). Effluent samples, however, were between 7.6 and 24.3 times higher than the upstream control. The resulting turbidity increase in the blending reach ranged from 0.5 and 8.9 NTU. Dissolved oxygen was slightly higher in the effluent sample than the upstream control, and concentrations observed in the blending reach were between 0.08 and 0.21 mg/L higher than the control. Effluent pH readings were as much as 0.92 units higher than the control, but blending reach pH was mostly unchanged. The largest difference in pH between the blending reach and the control was 0.07 units in the September 5, 2013, sample. Sand filter effluent conductivity was considerably lower than the upstream control, with the largest difference of 449 µS/cm observed in the August 15 sample. The remaining samples, however, had differences ranging between 144 and 170 µS/cm. Blending reach conductivity was between 1 µS/cm higher and 14 µS/cm lower than the control. TRC was between 0.22 to 0.82 mg/L higher in the outfall samples than the upstream control for all samples. With the exception of the August 15, 2013, sample, TRC concentrations were the same or lower in the blending reach than the upstream control. Sand filter backwash TRC was not analyzed during the August 29 sample trip. Temperature was nearly the same among all samples.

7.1.2.3 Softening Basin Blowdown

Turbidity of the softening basin blowdown effluent exceeded the instrument's 1000 NTU upper limit (Table 4), which resulted in blending reach turbidity being from 152 to 338 NTU higher than the upstream control. With the exception of the August 15, 2013, sample, dissolved oxygen concentrations were slightly lower in the effluent sample than the control. Despite this input, the dissolved oxygen in these blending reach samples was slightly higher (no more than 0.16 mg/L) than the control. Softening basin blowdown effluent had a higher pH than the upstream control and, although the increase was small, there was a consistent increase in blending reach pH as a result. The effluent pH was between 1.47 and 1.76 units higher than the control, and the blending reach was between 0.07 and 0.15 units higher. Effluent conductivity was much lower than the control site, ranging from 192 to 472 µS/cm lower than upstream. Conductivity in the blending reach, however, was nearly the same as the control during all four sample dates. TRC

was 0.57 mg/L for each of the three effluent samples, which was at least twice as high as the upstream control. TRC in the blending reach was lower than the control in each sample, however, and below detectable concentrations in the August 22, 2013, sample. As was the case with the other two effluent types, little or no difference in temperature was observed.

Table 2. Missouri River Water Quality Field Parameters: Pre-Sedimentation Blowdown

	Station	D.O. (mg/L)	pH	cond (µS/cm)	temp (ºC)	turb (NTU)	TRC (mg/L)	velocity (ft/s)	discharge duration
Aug. 15	upstream control	7.09	8.04	697	25.8	87.1	0.18	3.1	3 min.
	upstream duplicate	7.06	8.05	697	25.9	78.8	0.39	3.1	
	effluent	7.52	8.11	660	25.1	>1000	0.15	N/A	
	downstream	7.06	8.05	695	25.9	120	0.20	- 0.14	
Aug. 22	upstream control	7.64	8.30	704	26.4	55.8	0.12	2.96	7 min.
	effluent	8.05	8.47	699	26.4	>1000	1.8	N/A	
	downstream	7.66	8.37	705	26.4	55.7	0.09	1.46	
Aug. 29	upstream control	7.37	8.37	694	28.5	37.9	0.14	2.58	8 min.
	upstream duplicate	7.37	8.36	694	28.5	30.2	0.10	2.62	
	effluent	7.05	8.45	675	28.6	>1000	0.00	N/A	
	downstream	7.24	8.41	698	29.6	39.9	--	2.47	
Sept. 5	upstream control	7.45	8.26	808	27.3	34.4	0.14	2.94	6 min.
	upstream duplicate	7.41	8.27	807	27.4	32.8	0.10	3.80	
	effluent	7.75	8.37	783	27.1	>1000	0.17	N/A	
	downstream	7.50	8.32	804	27.4	40.1	0.11	2.18	

Table 3. Missouri River Water Quality Field Parameters: Sand Filter Backwash

	Station	D.O. (mg/L)	pH	cond (µS/cm)	temp (ºC)	turb (NTU)	TRC (mg/L)	velocity (ft/s)	discharge duration
Aug. 15	upstream control	7.08	8.05	698	26.0	78.2	0.16	1.9	3 min.
	effluent	8.06	8.97	249	25.6	594	0.38	N/A	
	downstream	7.16	8.06	697	26.0	85.4	0.18	0.84	
Aug. 22	upstream control	7.52	8.34	704	26.5	53.9	0.11	3.28	10 min.
	upstream duplicate	7.68	8.34	705	26.4	49.0	0.08	3.01	
	effluent	7.93	8.56	534	26.8	695	0.93	N/A	
	downstream	7.72	8.35	705	26.6	54.4	0.08	2.45	
Aug. 29	upstream control	7.42	8.35	696	28.9	31.2	--	2.42	8 min.
	effluent	7.77	8.98	544	29.3	424	--	N/A	
	downstream	7.63	8.38	682	29.3	41.1	--	1.71	
Sept. 5	upstream control	7.55	8.28	804	27.6	31.3	0.22	3.05	11 min.
	effluent	7.90	9.00	660	27.5	761	0.59	N/A	
	downstream	7.75	8.35	794	27.7	37.2	0.14	1.92	

Table 4. Missouri River Water Quality Field Parameters: Softening Basin Blowdown

	Station	D.O. (mg/L)	pH	cond (µS/cm)	temp (ºC)	turb (NTU)	TRC (mg/L)	velocity (ft/s)	discharge duration
Aug. 15	upstream control	7.18	8.00	698	26.2	81.5	0.23	1.9	9 min.
	effluent	7.83	9.76	226	27.4	>1000	0.57	N/A	
	downstream	7.28	8.15	695	26.2	292	0.02	0.99	
Aug. 22	upstream control	7.65	8.37	704	26.8	51.1	0.07	3.06	8 min.
	effluent	7.44	10.08	512	27.7	>1000	0.57	N/A	
	downstream	7.81	8.44	703	26.8	288	0.00	1.60	
Aug. 29	upstream control	7.59	8.37	697	29.3	33.9	--	0.89	11 min.
	effluent	7.13	9.97	504	29.5	>1000	--	N/A	
	downstream	7.66	8.44	690	29.7	186	--	0.51	
Sept. 5	upstream control	7.86	8.31	799	28.0	32.7	0.23	3.71	12 min.
	effluent	7.64	9.78	596	27.4	>1000	0.57	N/A	
	downstream	7.90	8.41	799	28.2	66.5	0.05	2.00	

7.1.3 Water Quality Chemical Constituent Analysis

Dissolved metals results for water quality grab samples collected from the outfall, the upstream control, and the blending reach downstream of the outfall for each effluent type are presented in Tables 5-7. Values that differed from the control are highlighted in gray. Results are presented separately for each effluent type. None of the metals tested in this study occurred in concentrations that exceeded Missouri's Water Quality Standards for the protection of aquatic life (MDNR 2014).

7.1.3.1 Pre-Sedimentation Blowdown

With the exception of the August 15, 2013, sample, iron, aluminum, manganese, and zinc were consistently higher in the pre-sedimentation effluent sample than the control (Table 5). Manganese in the effluent was present in high concentrations relative to the control, ranging from 73 to 127 times higher. Concentrations of manganese in the blending reach also were higher than the control, with the exception of the August 22, 2013, sample in which both the upstream and blending reach samples had similar levels. The remaining metals either exhibited no pattern relative to the outfall or were present in concentrations below detectable levels. Hardness was slightly lower in the effluent samples, but the blending reach and upstream control were similar. Although TSS was between 27 and 62 times higher in the effluent sample than the control, the blending reach TSS showed only moderate increases.

7.1.3.2 Sand Filter Backwash

The sand filter effluent sample results were variable (Table 6). Calcium, magnesium, aluminum, arsenic, barium, and nickel concentrations all were lower in the effluent samples than the upstream control. Conversely, iron was higher in three of the four effluent samples collected. In the remaining sample (August 15), the iron concentration was higher in the blending reach than either the effluent or the upstream control. With the exception of the August 22, 2013, sample, chromium also was present in higher concentrations in the effluent samples. Manganese was below detectable concentrations in all but the August 29, 2013, effluent sample, which was nearly 15 times higher than the control. No patterns were observed for the remaining metals. Effluent hardness levels were less than half of the upstream control; however, blending reach hardness tended to be similar to or only slightly lower than the control. Effluent TSS levels were between three and seven times higher than the control, which resulted in slightly higher levels in the blending reach.

7.1.3.3 Softening Basin Blowdown

Compared to the upstream control, the concentrations of several metals in the softening basin effluent sample were substantially lower (Table 7). Calcium, magnesium, arsenic, and barium concentrations in the effluent samples were a fraction of the control samples. Iron concentrations in the effluent were variable. The August 15 effluent sample had lower iron concentrations than either the control or blending reach samples, and iron was below detectable concentrations in the August 22, 2013, and September 5 effluent samples. Manganese was below detectable concentrations in each effluent sample. Aluminum concentrations were below detectable or practical quantitation limits for all effluent samples. In the August 15 sample,

aluminum was higher in the control and blending reach samples than any of the subsequent dates. In addition, aluminum was higher in the control sample than either the effluent or blending reach sample on August 22, 2013. Outfall hardness levels were roughly half of the upstream control in each of the four sample dates. There was, however, little or no difference between the blending reach and control hardness values. The remaining metals occurred either in concentrations below detectable levels, or they were similar among sample locations. TSS present in the softening basin effluent was the highest of the three effluent types. TSS in the effluent samples ranged from 38,100 mg/L to 55,300 mg/L and resulted in consistently high TSS levels in the blending reach.

Table 5. Missouri River Dissolved Metals: Pre-sedimentation Blowdown

		Hard	TSS	Ca	Mg	K	Na	Fe	Al	Sb	As	Ba	Be	Cd	Cr	Cu	Pb	Mn	Ni	Se	Ag	Tl	Zn
	Station	mg/L						µg/L															
Aug. 15	upstr. control	248	119	62.7	22.2	8.15	61.2	11.4	20.1	*	4.46	109	*	*	0.54†	2.17	*	1.74	2.33	2.63†	*	*	3.01
	upstr. duplicate	245	95	61.8	22.0	8.06	60.3	11.5	20.8	*	4.43	108	*	*	*	2.21	*	1.65	2.14	2.51†	*	*	4.67
	effluent	232	4050	58.9	20.7	7.72	57.9	11.4	20.9	0.51†	4.12	104	*	*	0.95†	2.05	*	222	2.33	2.32†	*	*	7.33
	downstream	248	167	62.6	22.2	8.13	61.0	11.1	21.3	0.50†	4.77	118	*	*	0.53†	2.37	*	8.57	2.33	2.60†	*	*	3.29
Aug. 22	upstr. control	278	96	69.8	25.2	8.99	71.6	5.36	9.32†	0.53†	4.86	110	*	*	0.55†	2.15	*	0.80†	2.05	2.58†	*	*	5.37
	effluent	249	2440	62.5	22.6	8.40	69.8	15.7	25.6	0.56†	4.76	104	*	*	1.56	2.01	*	90.9	2.25	2.51†	*	*	10.2
	downstream	276	116	69.3	25.0	9.09	71.4	6.14	9.94†	0.52†	4.90	110	*	*	0.62†	2.02	*	0.99†	2.04	2.72†	*	*	3.98
Aug. 29	upstr. control	245	74	61.7	22.0	8.27	65.3	7.90	8.11†	0.54†	5.72	101	*	*	4.76	1.76	*	2.37	2.18	2.70†	*	*	3.58
	upstr. duplicate	251	70	63.6	22.5	8.30	65.4	6.53	8.42†	0.56†	5.80	99.5	*	*	5.75	1.77	*	2.30	2.16	2.86†	*	*	3.28
	effluent	237	4580	59.7	21.4	8.01	62.9	141	72.4	0.54†	4.97	101	*	*	3.65	2.01	0.66†	173	2.48	2.71†	*	*	7.34
	downstream	246	92	62.4	22.0	8.19	64.6	7.93	9.75†	0.56†	5.76	100	*	*	5.62	1.70	*	7.37	2.16	2.92†	*	*	3.04
Sept. 5	upstr. control	239	70	59.1	22.2	7.73	72.0	5.71	3.82†	0.57†	4.49	102	*	*	*	1.62	*	1.00	0.92†	2.23†	*	*	2.31
	upstr. duplicate	236	70	58.4	21.9	7.73	71.2	2.15†	5.19†	0.56†	4.43	99.7	*	*	*	1.64	*	1.01	1.02	2.09†	*	*	2.69
	effluent	215	1870	52.5	20.4	7.77	73.4	12.5	14.3	0.60†	4.04	88.0	*	*	0.98†	1.72	*	118	0.96†	2.22†	0.52†	*	5.39
	downstream	237	88	58.8	22.0	7.80	71.6	3.43†	4.76†	0.57†	4.51	99.4	*	*	*	1.61	*	3.51	0.96†	2.17†	*	*	2.54

*Below detectable concentrations.
†Estimated value, below practical quantitation limits.

Table 6. Missouri River Dissolved Metals: Sand Filter Backwash

		Hard	TSS	Ca	Mg	K	Na	Fe	Al	Sb	As	Ba	Be	Cd	Cr	Cu	Pb	Mn	Ni	Se	Ag	Tl	Zn
	Station	mg/L						µg/L															
Aug. 15	upstr. control	245	116	62.0	22.0	8.07	60.5	10.4	18.9	*	4.42	108	*	*	0.50[a]	2.20	*	1.59	2.13	2.39[a]	*	*	2.68
	effluent	124	386	30.2	11.9	7.94	63.4	10.3	2.54[a]	*	1.37	31.2	*	*	1.88	0.99[a]	*	*	0.88[a]	2.59[a]	*	*	2.57
	downstream	n/a	140	61.5	21.5	7.99	60.0	25.7	18.3	*	4.35	109	*	*	*	2.17	*	2.18	2.15	2.47[a]	*[b]	*	3.23
Aug. 22	upstr. control	268	93	68.1	23.9	8.56	68.6	6.61	12.3	0.52[a]	4.94	111	*	*	*	2.07	*	0.70[a]	2.06	2.59[a]	*	*	2.62
	upstr. duplicate	276	98	69.6	24.9	8.93	71.5	5.36	15.1	0.53[a]	4.90	111	*	*	*	2.06	*	0.74[a]	2.02	2.64[a]	*[b]	*	2.80
	effluent	133	569	32.4	12.7	8.39	72.6	10.3	3.45[a]	0.51[a]	1.44	35.0	*	*	2.03	1.16	*	*	0.98[a]	2.47[a]	*	*	2.55
	downstream	268	101	67.4	24.1	8.61	69.4	5.79	11.4	0.52[a]	4.90	111	*	*	*	2.07	*	0.71[a]	2.01	2.60[a]	*	*	2.66
Aug. 29	upstr. control	242	70	61.0	21.7	8.00	63.2	3.46[a]	6.96[a]	0.55[a]	5.80	101	*	*	5.00	1.76	*	1.16	3.94	2.84[a,b]	*	*	2.96
	effluent	141	498	36.6	12.1	8.04	66.1	2.43[a]	6.27[a]	0.55[a]	2.05	47.9	*	*	3.33	1.02	*	17.3	1.20	2.45[a]	*	*	2.11
	downstream	242	97	61.4	21.6	8.17	64.4	3.53[a]	7.68[a]	0.55[a]	5.64	102	*	*	5.16	1.76	*	2.83	2.17	2.69[a]	*	*	3.13
Sept. 5	upstr. control	238	70	58.9	22.2	7.82	72.1	2.87[a]	8.55[a]	0.58[a]	4.50	100	*	*	*	1.65	*	1.15	0.99[a]	2.16[a]	*	*	2.63
	effluent	134	439	31.4	13.6	7.83	75.1	5.50	*	0.57[a]	1.20	36.5	*	*	1.80	0.84[a]	*	*	*	2.03[a]	*	*	1.95
	downstream	234	79	58.1	21.7	7.85	72.7	4.23[a]	4.35[a]	0.57[a]	4.36	95.7	*	*	*	1.61	*	1.61	0.97[a]	2.08[a]	*	*	2.93

*Below detectable concentrations.
[a]Estimated value, below practical quantitation limits.
[b]Estimated value, quality control data outside limits.

Table 7. Missouri River Dissolved Metals: Softening Basin Blowdown

		Hard	TSS	Ca	Mg	K	Na	Fe	Al	Sb	As	Ba	Be	Cd	Cr	Cu	Pb	Mn	Ni	Se	Ag	Tl	Zn
	Station	mg/L						µg/L															
Aug. 15	upstr. control	255	116	64.8	22.6	8.41	61.9	8.94	20.4	0.50†	4.42	109	*	*	*	2.22	*	2.07	2.15	2.48†	*	*	2.86
	effluent	104	55,300	23.6	11.0	8.61	62.1	5.38	2.95†	0.56†	1.30	33.4	*	*	2.83	1.41	*	*	0.97†	2.33†	*	*	2.13
	downstream	245	391	61.3	22.4	8.08	60.1	10.7	17.8	*	3.99	107	*	*	*	1.91	*	2.04	1.99	2.40†	*	*	3.21
Aug. 22	upstr. control	269	99	67.8	24.3	8.77	69.5	8.04	10.7	0.52†	4.89	110	*	*	*	2.10	*	0.83†	2.05	2.54†	*	*	2.50
	effluent	130	27,200	24.0	16.9	9.17	71.0	*	*	0.59†	1.31	38.9	*	*	1.21	1.70	*	*	1.46	2.43†	*	*	2.89
	downstream	278	152	67.5	26.5	9.02	72.3	2.97	4.95†	0.52†	3.82	105	*	*	*	1.72	*	1.61	1.90	2.57†	*	*	2.33
Aug. 29	upstr. control	242	71	61.2	21.6	8.05	63.4	2.77†	7.56†	0.55†	5.85	102	*	*	5.74	1.76	*	2.51	2.19	2.96†	*	*	2.96
	effluent	101	48,500	20.5	12.1	8.68	64.1	6.18	2.61†	0.65†	1.02	34.6	*	*	1.47	1.37	*	*	1.50	2.38†	*	*	2.64
	downstream	240	225	60.1	21.9	8.03	63.7	6.69	5.61†	0.55†	5.13	99.7	*	*	5.15	1.58	*	2.22	2.06	2.59†	*	*	3.01
Sept. 5	upstr. control	242	70	59.8	22.6	7.93	72.7	1.37†	3.81†	0.58†	4.50	100	*	*	*	1.67	*	1.29	1.01	2.09†	*	*	2.58
	effluent	111	38,100	18.4	15.9	8.15	73.4	*	*	0.63†	0.88†	32.7	*	*	1.25	1.06	*	*	0.71†	1.99†	*	*	2.02
	downstream	236	176	57.5	22.5	7.75	71.7	2.73†	3.17†	0.58†	3.99	96.7	*	*	*	1.47	*	1.78	0.86†	2.13†	*	*	2.64

*Below detectable concentrations.
†Estimated value, below practical quantitation limits.

7.1.4 Data Sonde Continuous Monitoring Data

Data sondes were placed in three locations near the south bank of the Missouri River to measure temperature, pH, conductivity, turbidity, and dissolved oxygen at 2-minute intervals from August 8 to September 6, 2013. Due to the time interval used in collecting readings, it was necessary to deactivate the sondes' cleaning mechanism to maintain battery life for a 7-day deployment period. Although most parameters showed no negative effects due to fouling, occasional erratic turbidity readings resulted from a lack of regular cleaning. During quality control review of the sonde files, readings that were clearly erroneous were removed from the figures presented in this section. If it was unclear whether data points were in error, they were kept in the graph.

To demonstrate differences among study sites, data from each of the three sondes are presented on the same chart when the y-axis scale allows. Specifically, conductivity and turbidity are grouped together as are pH and dissolved oxygen. On days in which water quality grab samples were collected, investigators were able to note exactly when specific discharge events occurred. Representative sonde data recorded within that time frame for the August 15, 2013, sample trip are presented in separate figures.

7.1.4.1 Data Sonde Conductivity and Turbidity

During the first week of sonde deployment (August 8-16, 2013), the river stage was higher than the remainder of the study, which corresponded to lower conductivity (Figure 7 vs. Figures 8-10). As the river level fell, conductivity increased and remained relatively consistent, with the exception that conductivity nearest the outfall tended to show very small episodic decreases that coincided with turbidity spikes. Turbidity exhibited repeated, consistent spikes in response to discharge events for the duration of the study (Figures 7-10). The magnitude of turbidity spikes was highest at the outfall location, and, although increases also were recorded at the downstream station, they tended to be much smaller. The turbidity "noise" present on August 14, 2013, was intentionally left in Figure 7 for demonstration purposes and represents the type of information deleted from subsequent charts.

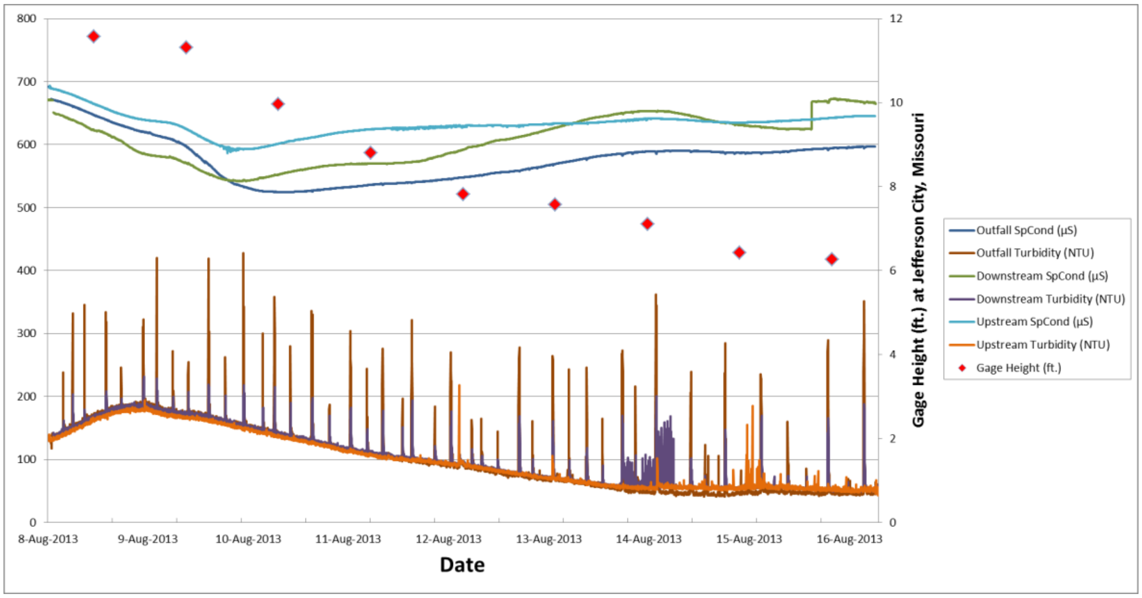

Figure 7. Week 1: August 8-16 conductivity and turbidity data sonde readings.

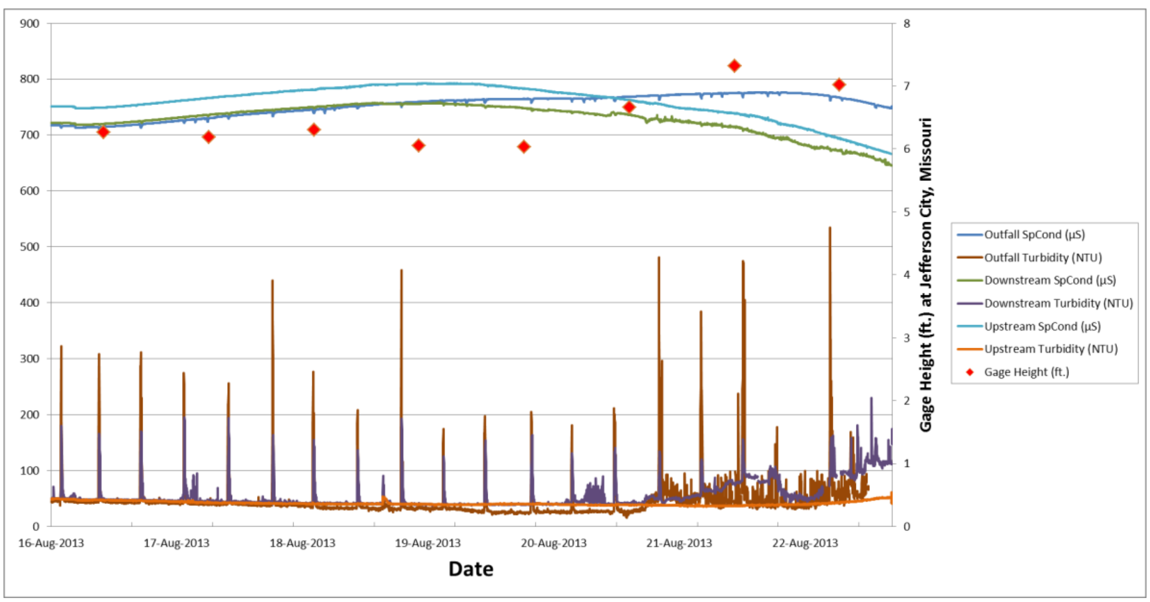

Figure 8. Week 2: August 16-23 conductivity and turbidity data sonde readings.

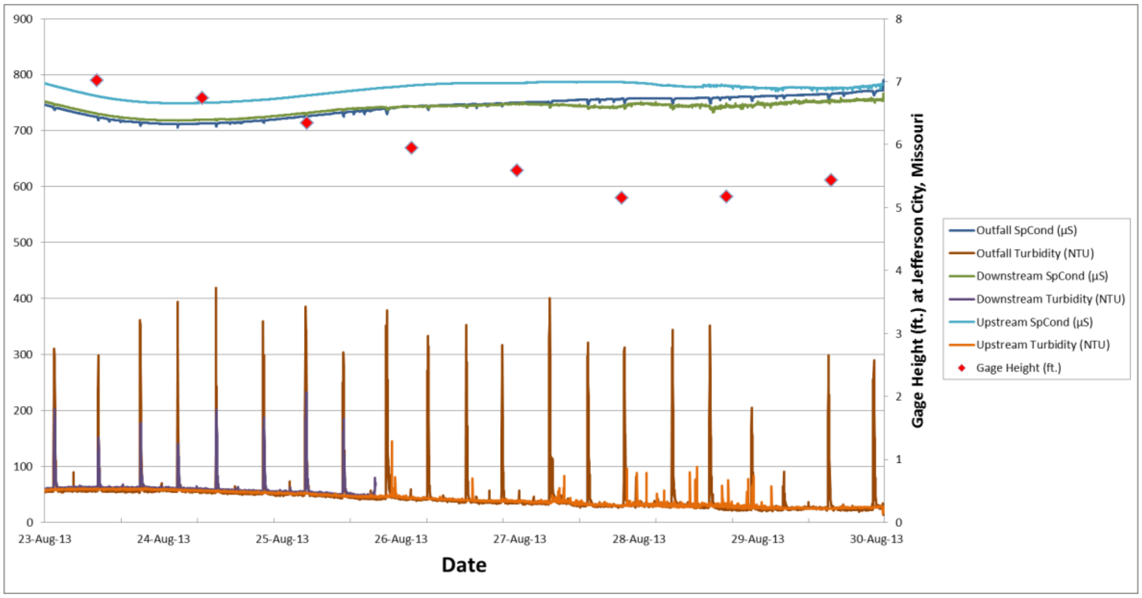

Figure 9. Week 3: August 23-30 conductivity and turbidity data sonde readings.

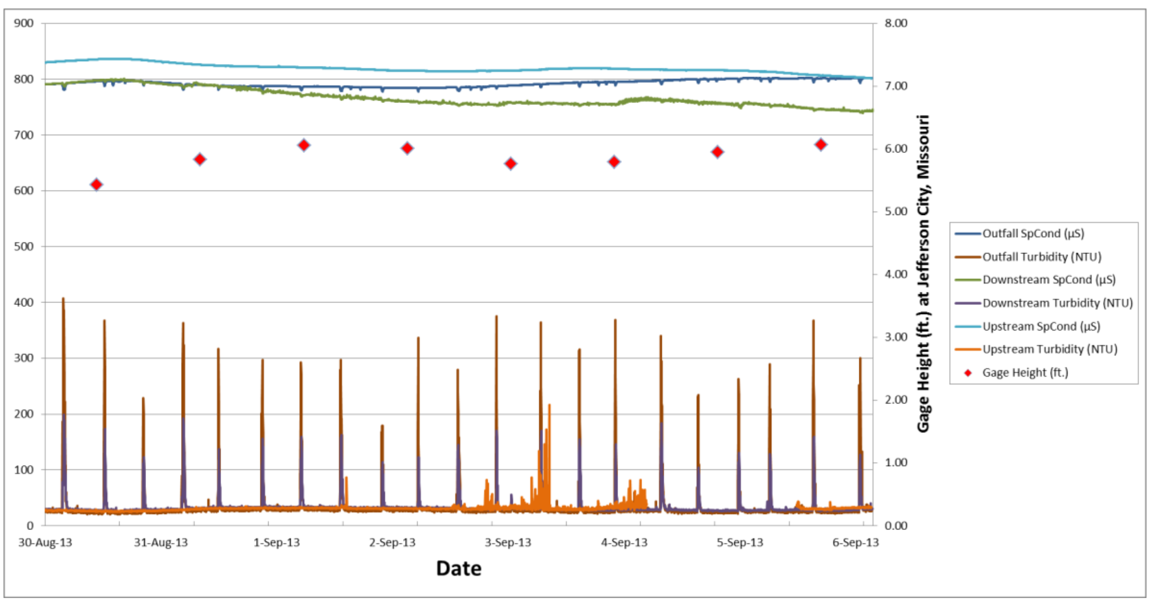

Figure 10. Week 4: August 30-September 6 conductivity and turbidity data sonde readings.

7.1.4.2 Data Sonde Dissolved Oxygen and pH

After the Missouri River stage stabilized, dissolved oxygen concentrations increased and exhibited a pattern of daily fluctuations consistent with algal oxygen production and use (Figure 11). Although this diel pattern held throughout the study period, from August 30 to September 3, 2013, the overall dissolved oxygen cycle was slightly lower than the remaining time (Figures 13 and 14). Dissolved oxygen patterns were nearly identical among stations. However, sonde readings showed a regular pattern of slight pH increases in the two downstream locations,

whereas the upstream sonde exhibited none of these spikes. As was the case with turbidity, increases in pH were greater at the outfall station compared to the downstream site. This pattern of regular pH spikes was consistent among all four weeks during the deployment (Figures 11-14).

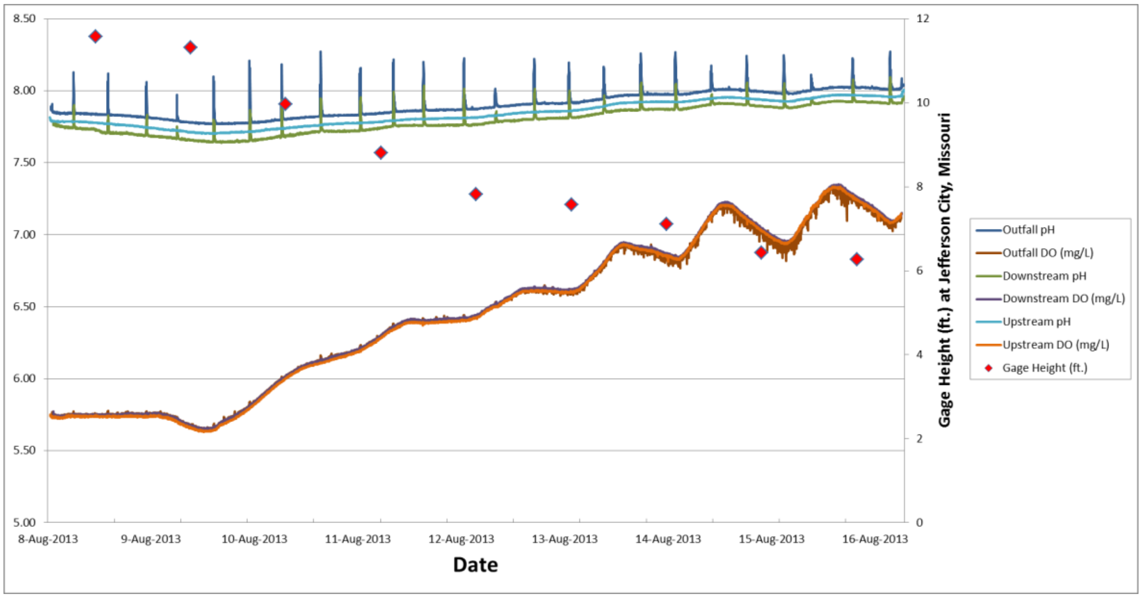

Figure 11. Week 1: August 8-16 pH and dissolved oxygen data sonde readings.

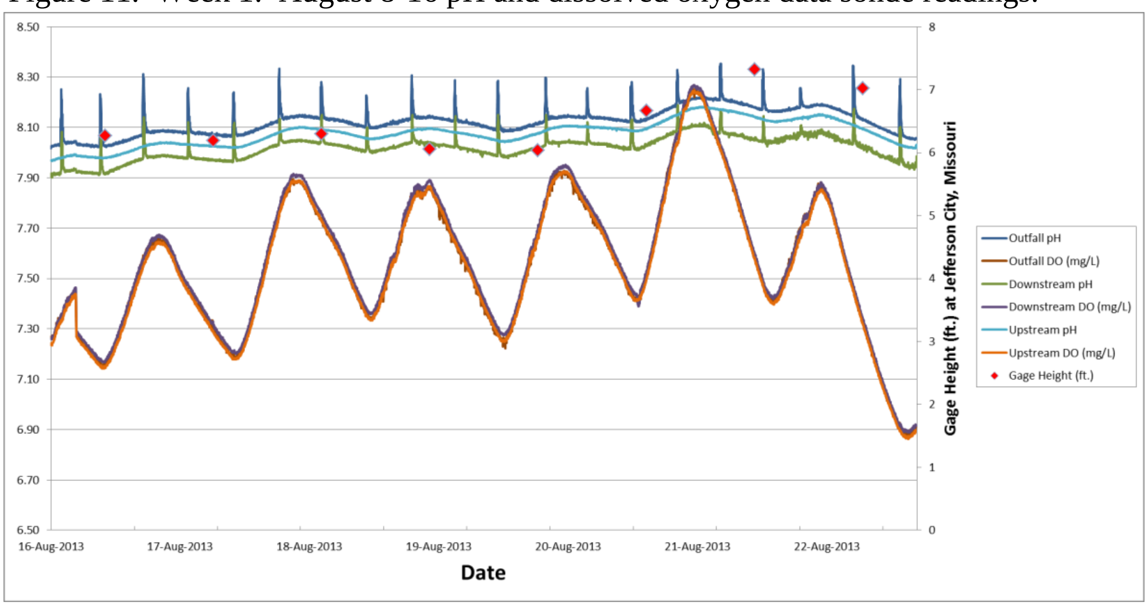

Figure 12. Week 2: August 16-23 pH and dissolved oxygen data sonde readings.

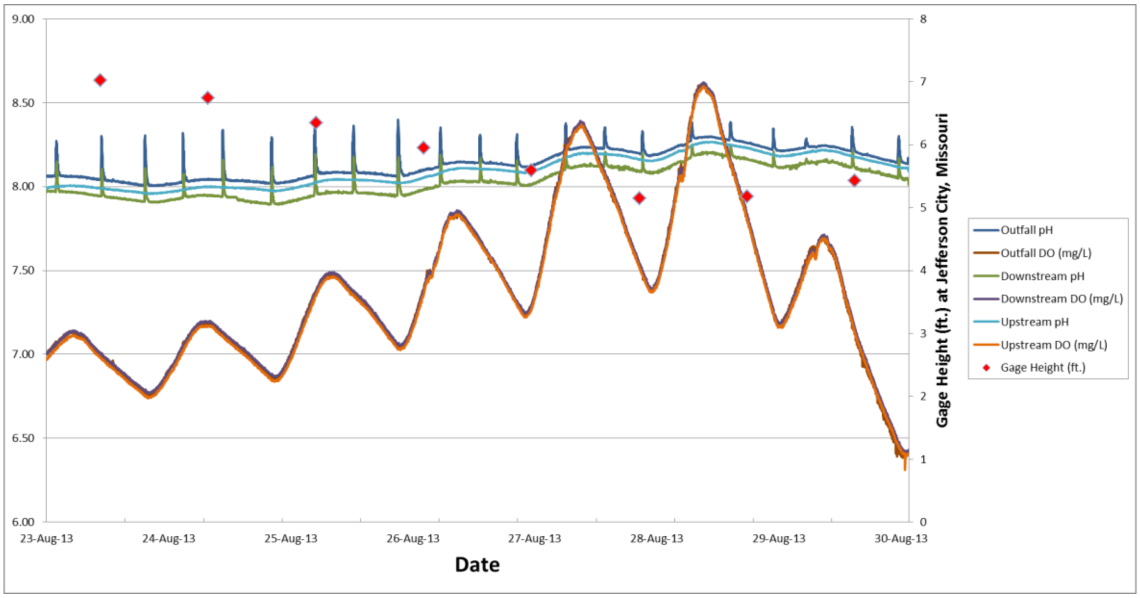

Figure 13. Week 3: August 23-30 pH and dissolved oxygen data sonde readings.

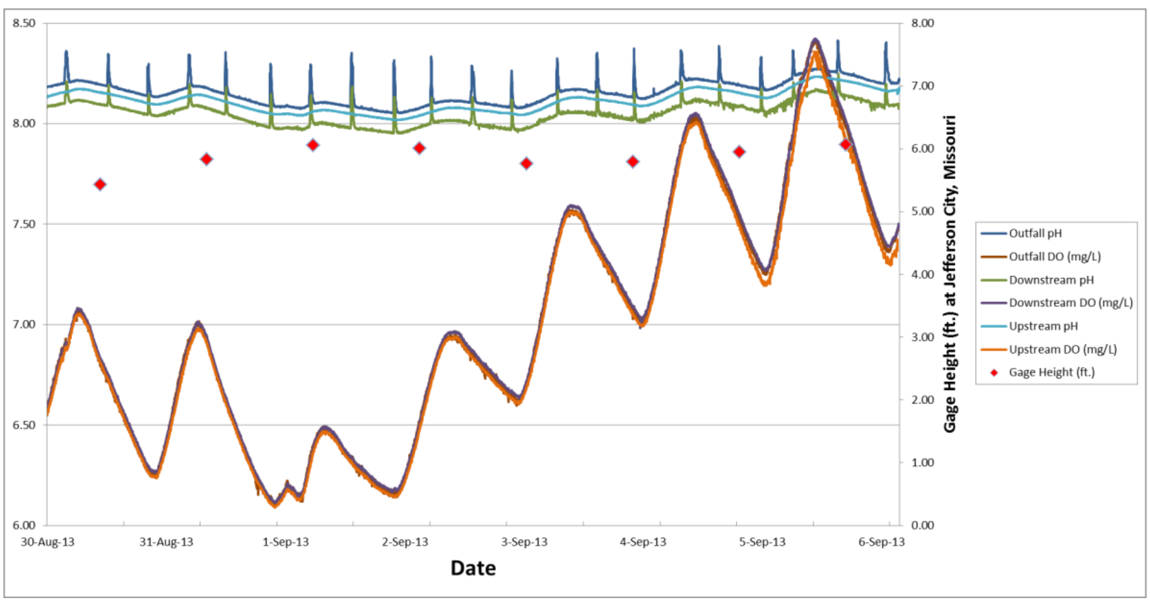

Figure 14. Week 4: August 30-September 6 pH and dissolved oxygen data sonde readings.

7.1.4.3 Data Sonde Temperature

Because there was very little difference in temperature among the three stations, data from all four weeks were combined. Temperature patterns were so similar among stations that it is difficult to differentiate the three data sets in Figure 15. Higher Missouri River flows created a less predictable temperature regime during the first few days of sonde deployment (Figure 15). As flows decreased and became more stable over time, temperature throughout the remainder of the study period exhibited normal fluctuations according to warming patterns throughout the day. Temperature varied by no more than 5°C during the study.

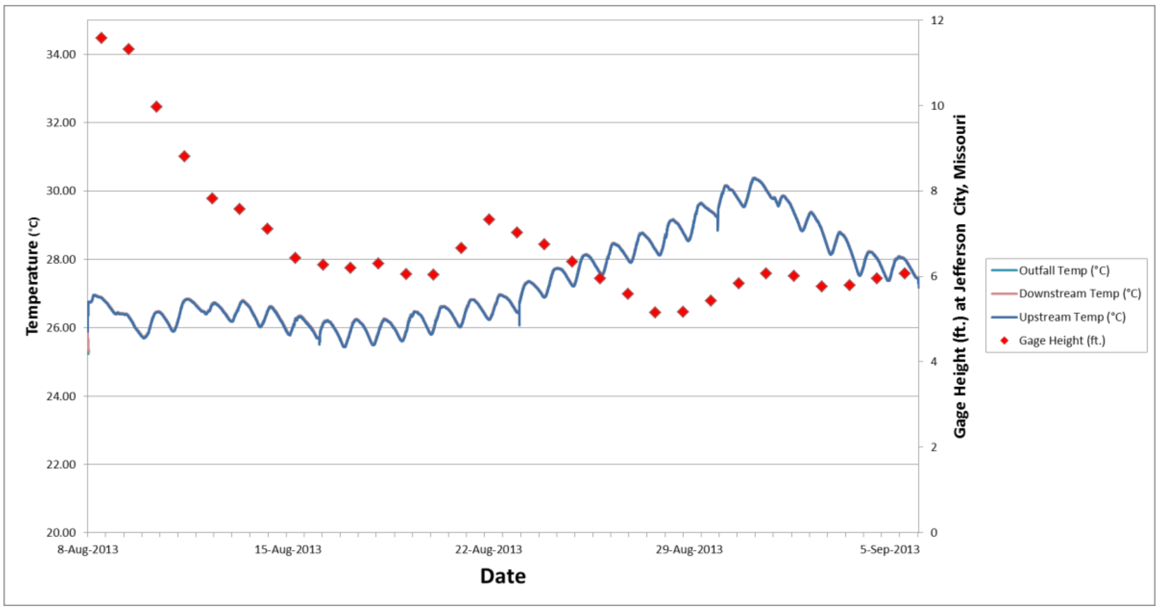

Figure 15. August 8-September 6 data sonde temperature readings.

7.1.4.4 Data Sonde Readings During Grab Sample Collection

The figures in this section present turbidity, conductivity, dissolved oxygen, and pH sonde readings for the August 15, 2013, grab sample collection trip (Figures 16-18). Patterns of these water quality parameters were generally similar among weeks; therefore, only the first week's information is presented. In addition, fewer erroneous readings were observed during the first week, which resulted in all three sondes' data sets providing the best representation of water quality response to the individual effluent types. The specific time frame in these figures brackets the three effluents that were released by MAWC personnel for benefit of the study.

Turbidity at the outfall and downstream stations was highest during softening basin discharge, whereas the remaining two releases appeared to result in turbidity changes that were similar to one another (Figure 16). The softening basin effluent resulted in an increase in pH, but neither the pre-sedimentation blowdown nor the sand filter backwash had any effect on pH (Figure 17). A slight decline in conductivity was observed during the sand filter and softening basin discharges, but the change was minor (Figure 18). None of the releases affected dissolved oxygen concentrations (Figure 17).

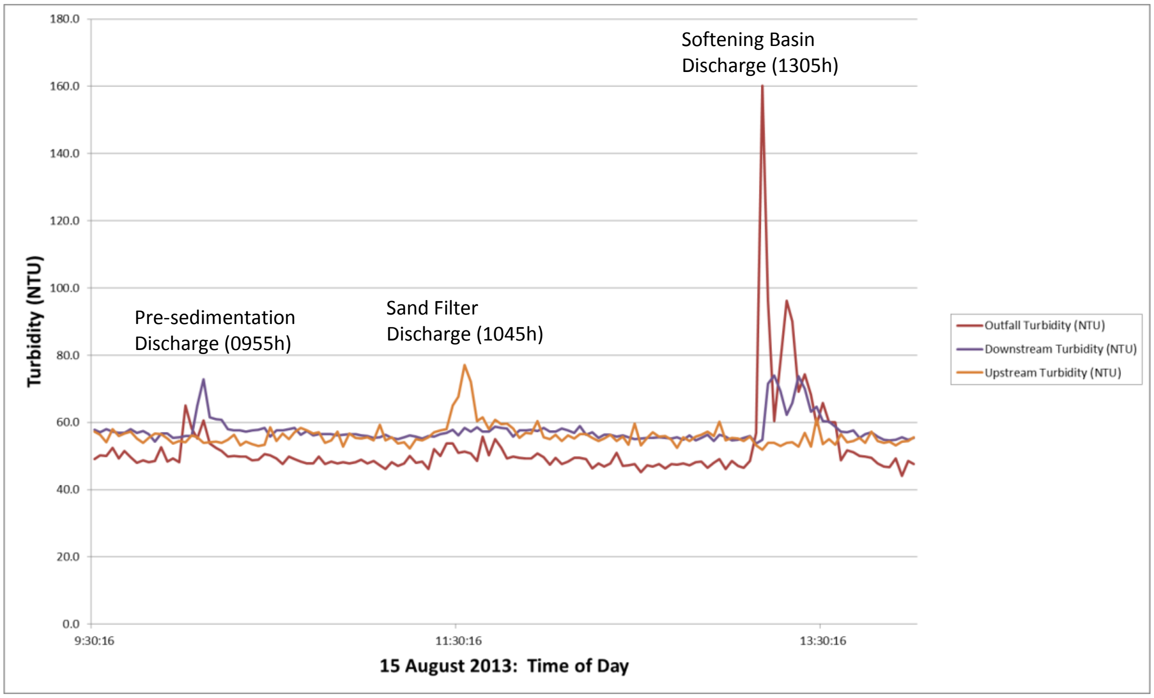

Figure 16. Sonde turbidity readings during August 15 water quality sample collection.

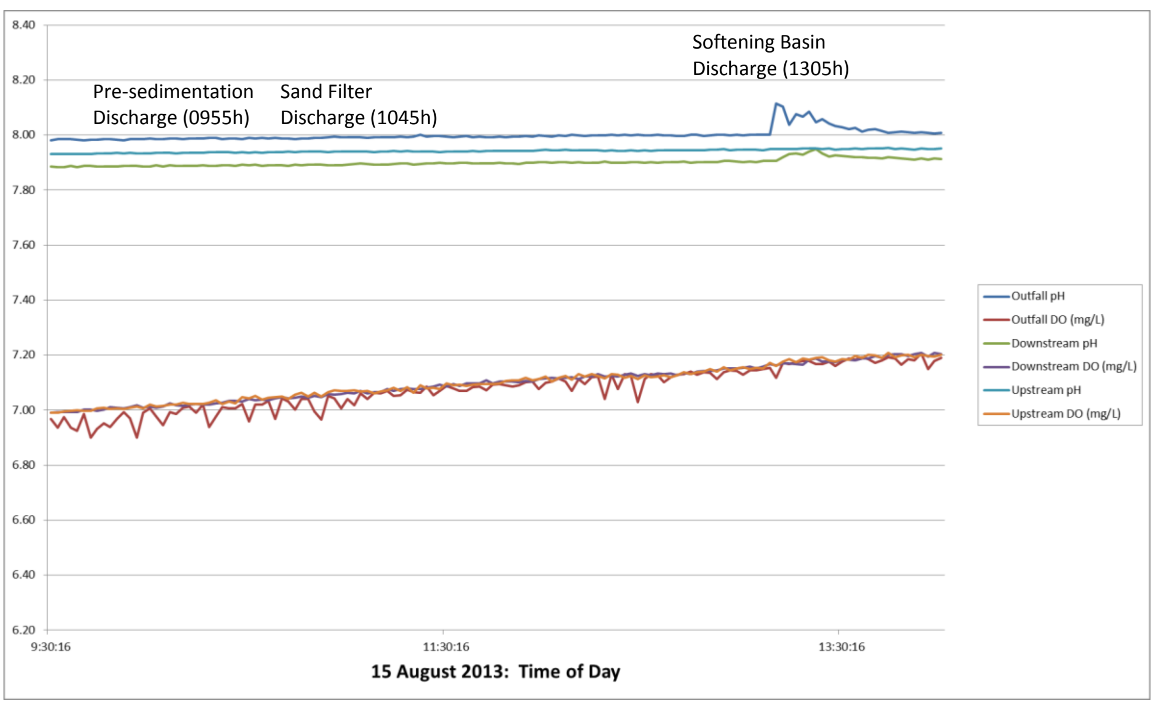

Figure 17. Sonde pH and dissolved oxygen readings during August 15 water quality sample collection.

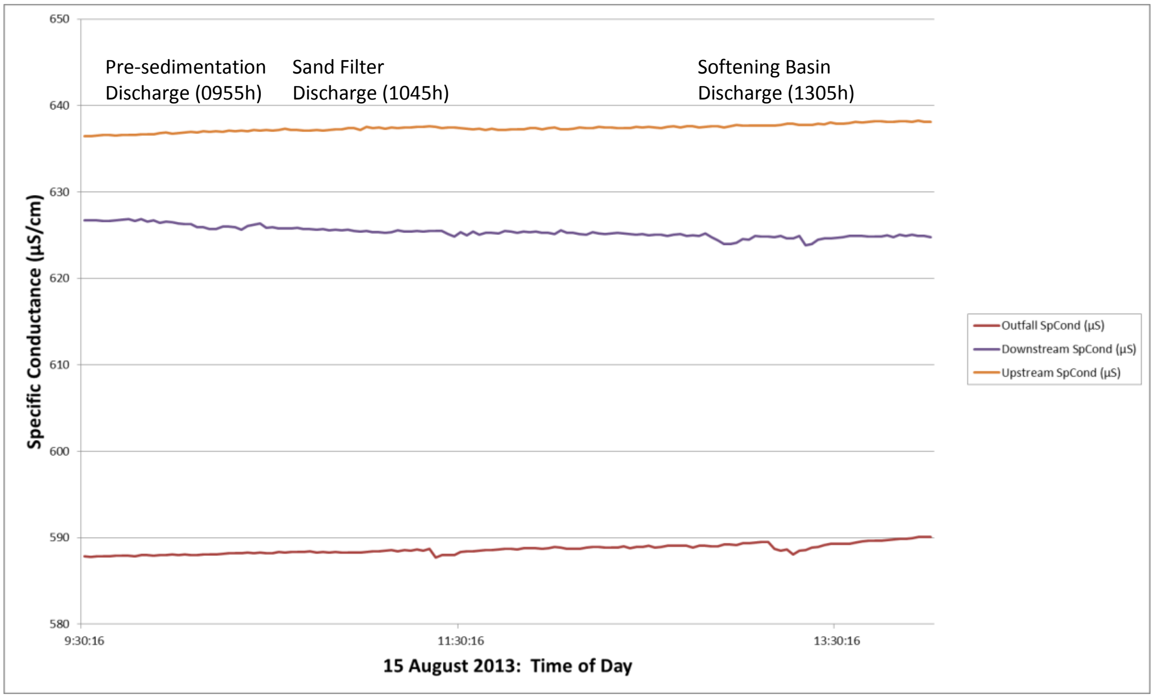

Figure 18. Sonde conductivity readings during August 15 water quality sample collection.

7.2 Hester-Dendy Macroinvertebrate Community Assessment

Macroinvertebrate data used in statistical analysis for the following section is presented in Appendix C.

7.2.1 Hester-Dendy Statistical Analysis

Although the mean number of individuals collected in 25 percent Hester-Dendy subsamples was higher at the upstream control station (*n*=1237) compared to either the outfall (*n*=706) or downstream station (*n*=754), there was no statistically significant difference (*p*=0.449) among the three stations (Table 8, Figure 19). Macroinvertebrate density [number of individuals per square foot (**sq. ft.**)] was calculated for each station as well. The upstream control had 1648.3 per sq. ft., the outfall had 940.4 per sq. ft., and the downstream station had 1004.2 individuals per sq. ft. (Figure 19). There was, however no statistically significant difference in density among stations (*p*=0.449).

Means of the TR, EPTT, BI, and SDI biological metrics were compared statistically among stations (Table 8, Figure 20). There was a significant difference (*p*=0.003) in TR among stations with Hester Dendy samplers. The upstream control station had a mean TR of 17, the outfall station had 24 taxa, and the downstream station had a TR of 29. Although there were fewer EPTT in the upstream control sample (10) than the outfall (12) and downstream stations (14), the difference was not statistically significant (*p*=0.124). A significant difference (*p*=0.034) in mean BI values among stations was observed. The control station mean BI value (4.6) was

significantly lower compared to the outfall (5.0) but not when compared to downstream (4.9). There was also a significant difference in mean SDI values (*p*=0.002) among stations. The control had a mean SDI of 1.58, which was significantly lower than both the outfall (2.24) and downstream station (2.18).

Density of TR and density of EPTT in the 25 percent subsample was statistically analyzed to determine whether there was a difference in these two biological metrics among stations. TR per sq. ft. was significantly lower (*p*=0.002) at the control site (6 taxa per sq. ft.) than either the outfall (8 taxa per sq. ft.) or the downstream (10 taxa per sq. ft.) stations. There was, however, no significant difference in EPTT among stations (*p*=0.130). The mean density of EPTT at the control (3 per sq. ft.) was similar to the outfall (4 per sq. ft.) and the downstream (5 per sq. ft.) stations.

Table 8. Compiled ANOVA Results for Hester-Dendy Samplers

Station	Total Individuals (subsample)	Density (individuals per sq. ft.)	TR	EPTT	BI	SDI
Control (Station 3)	1236.667 ±463.419	1648.333 ±618.016	**17.333 ±4.726 vs 2,1**	10.000 ±1.000	**4.567 ±0.379 vs 2**	**1.583 ±0.215 vs 2,1**
Outfall (Station 2)	705.600 ±765.821	940.400 ±1020.938	**24.200 ±3.271 vs 3**	11.800 ±3.033	**5.040 ±0.134 vs 3**	**2.244 ±0.228 vs 3**
Downstream (Station 1)	753.600 ±409.775	1004.400 ±546.405	**28.600 ±2.074 vs 3**	13.600 ±1.517	4.900 0.141	**2.176 ±0.123 vs 3**
p-value	*p*=0.494	*p*=0.494	***p*=0.003**	*p*=0.124	***p*=0.034**	***p*=0.002**

Data presented are mean values with standard deviation. Hester Dendy *n*=5 arrays per station (*df*=4); total=13 due to 2 missing from control station (*df*=2). Bold=significant difference (*p*<0.05).

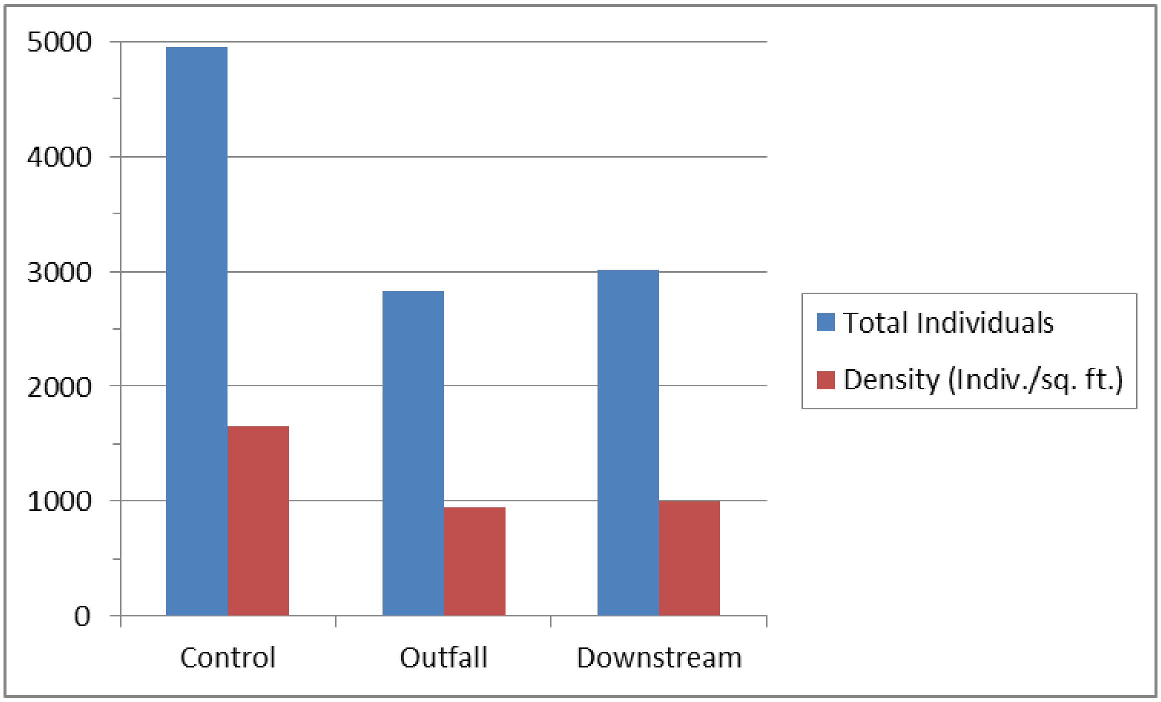

Figure 19. Total number of individuals (extrapolated from subsample) and density of macroinvertebrates colonizing Hester-Dendy samplers.

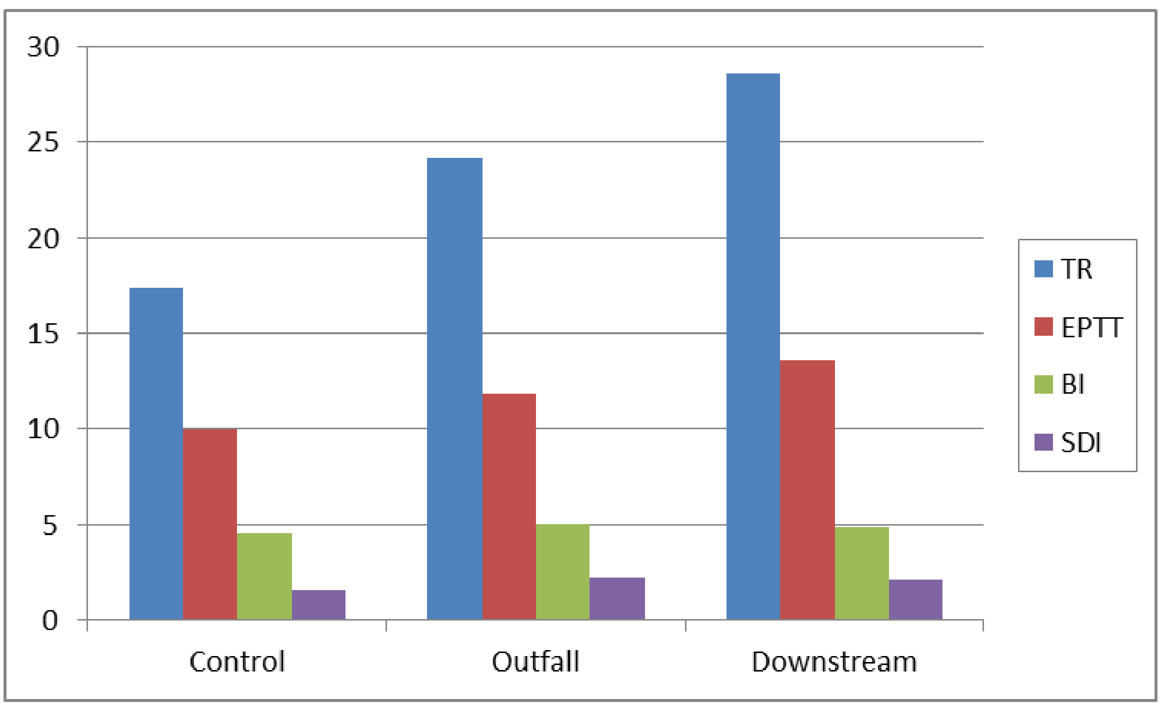

Figure 20. Mean values of biological metrics for each station using Hester-Dendy samplers.

7.2.2 Hester-Dendy Sampler Macroinvertebrate Community Composition

Replicate Hester-Dendy samples were pooled for each station, and several macroinvertebrate community attributes are presented in Table 9. The taxonomic order Trichoptera (caddisflies) was by far the most dominant group in Hester-Dendy samples for each station followed by Diptera (true flies), and Ephemeroptera (mayflies). Each order tended to be dominated by relatively few families and, in turn, genera. The order Trichoptera, for example, was made up almost entirely by one family (Hydropsychidae), the vast majority of which was the genus *Hydropsyche* and, to a lesser degree, *Potamyia flava*. The downstream station had the highest number of caddisfly taxa (7), followed by the outfall (6), and control (4) stations. Despite having fewer caddisfly taxa, the control sample had the highest Trichophtera percentage among samples. The outfall station had the lowest percentage of caddisflies.

Except for one or two individuals in the family Empididae found at each site, all Diptera were in the family Chironomidae. The outfall station had the most chironomid taxa (16), followed by the downstream (15), and control (9) sites. Two genera, *Polypedilum* and *Rheotanytarsus*, accounted for roughly 90 percent of chironomids at the downstream and outfall stations and over 98 percent of chironomids at the control station. Chironomids made up a higher percentage of the outfall sample than either the downstream or control samples.

The number of mayfly taxa ranged from 11 at the downstream station to six at the control site. Of these taxa, one genus or species was dominant at each site. At the downstream and outfall stations, the heptageniid mayfly *Maccaffertium mexicanum integrum* accounted for roughly 45 percent of all mayflies. At the control station, however, over 67 percent of mayflies were *Pseudocloeon* (Baetidae), with *M. m. integrum* and the families Caenidae and Isonychiidae making up the remainder of mayfly taxa. The control station had the lowest percentage of mayflies, whereas they were present in similar percentages at the outfall and downstream stations.

Stoneflies (Plecoptera) were present in low numbers at each station. The downstream and control stations each had three stonefly taxa, and the outfall station had a single stonefly taxon.

Other taxa that were found in relatively low numbers in Hester-Dendy subsamples included dragonflies and damselflies, aquatic worms, fingernail clams, Asian clams (*Corbicula* sp.), snails, and water mites.

Table 9. Missouri River Macroinvertebrate Composition: Hester-Dendy Samples Percent Dominant Taxa

↓Variable	Station→	control	outfall	downstream
Avg. TR		17.3	24.2	28.6
Avg. Number EPTT		10.0	11.8	13.6
% Ephemeroptera		10.5	16.5	15.0
% Plecoptera		0.3	0.1	0.2
% Trichoptera		63.9	49.9	55.2
% Dominant Families				
Hydropsychidae		63.8	49.3	54.9
Chironomidae		25.2	32.5	28.0
Heptageniidae		1.9	7.5	6.9
Baetidae		7.1	4.8	3.6
Caenidae		0.4	3.5	2.9
Isonychiidae		1.1	0.6	1.4
Planariidae		<0.1	0.0	0.7

7.3 Rock Basket Macroinvertebrate Community Assessment

Macroinvertebrate data used in statistical analysis for the following section is presented in Appendix C.

7.3.1 Rock Basket Statistical Analysis

There was a statistically different mean number of individuals collected on the river bottom using rock basket samplers among stations (p=0.003). There were 1867 individuals in the 25 percent subsample at the upstream control, which was significantly greater than the outfall (n=64, p=0.05) and downstream station (n=870, p=0.025) (Table 9, Figure 21).

Mean values of the biological metrics analyzed for this study are shown in Figure 22. With the exception of TR, the means of biological metrics were compared statistically among stations (Table 9) using the parametric ANOVA. Because the TR metric failed the normality test, the nonparametric Kruskal-Wallis One Way ANOVA on Ranks test was used. The median TR of the control and downstream stations (both 26) was slightly higher (p=0.071) than the outfall station (16). Although there were slightly fewer EPTT in the outfall sample (6) compared to the control and downstream station (10 for each), the difference was not statistically significant (p=0.258). BI values were significantly different (p=0.047) among rock basket samples. The mean BI value for the control station was 4.8, which was significantly lower (p=0.041) than the outfall value (5.7), but it was not significantly lower (p=0.498) than the downstream station (5.2). Likewise, there was no difference in BI between the outfall and downstream stations (p=0.185). SDI values were similar among sites (p=0.884), with the outfall station being only slightly lower (1.63) than either the control (1.74) or the downstream station (1.84).

Table 10. Compiled ANOVA and Kruskal-Wallis ANOVA on Ranks Results for Rock Basket Samplers

Station	Total Individuals (subsample)	TR	EPT Taxa	BI	SDI
Control (Station 3)	**1867.000 ±234.949 vs 2,1**	26.000 Median	10.000 ±1.000	**4.833 ±0.252 vs 2**	1.740 ±0.0529
Outfall (Station 2)	**64.000 ±55.651 vs 3,1**	16.000 Median	5.667 ±5.686	**5.733 ±0.351 vs 3**	1.627 ±0.890
Downstream (Station 1)	**870.333 ±599.614 vs 3,2**	26.000 Median	10.333 ±1.528	5.167 ±0.404	1.840 ±0.151
p-value	*p*=0.494	***p*=0.003**	*p*=0.124	***p*=0.034**	***p*=0.002**

Data presented are mean values with standard deviation, with the exception of TR, which is a median value. Rock Baskets n=3 per station or total=9 (df=8). Bold=significant difference (p<0.05).

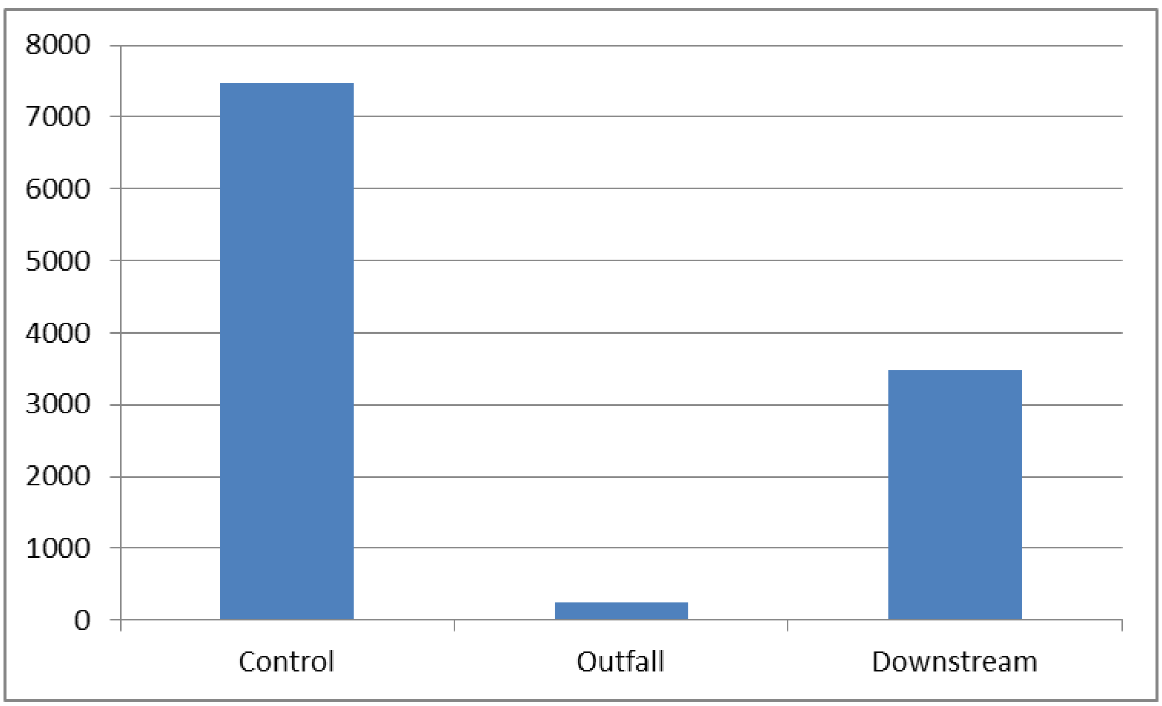

Figure 21. Total number of individuals (extrapolated from subsample) of macroinvertebrates colonizing rock basket samplers.

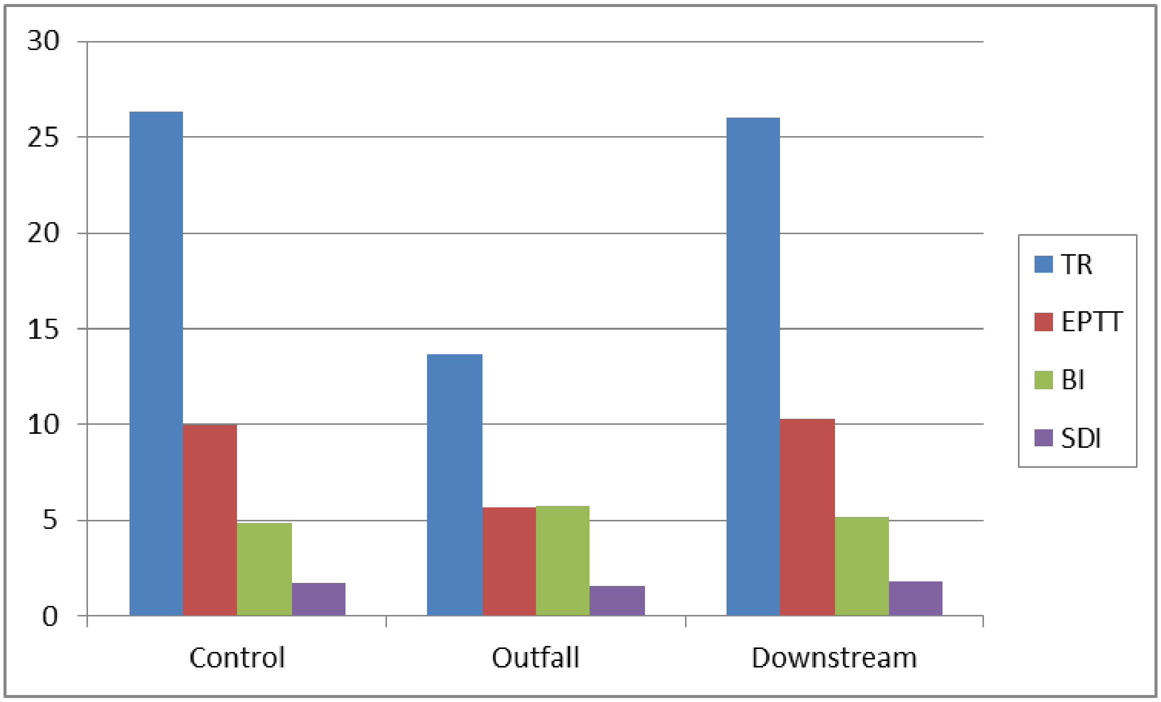

Figure 22. Mean values of biological metrics for each station using rock basket samplers.

7.3.2 Rock Basket Sampler Macroinvertebrate Community Composition

Replicate rock basket samples were pooled for each station, and macroinvertebrate community information is presented in Table 11. As was the case with the Hester-Dendy samples, caddisflies were the dominant taxa group among rock basket samples, followed by chironomids and mayflies.

Caddisflies made up nearly 75 percent of the overall sample at the downstream and control stations and well over half of the outfall sample. Hydropsychids accounted for over 99.9 percent of the caddisfly taxa at the control station, 99.4 percent at the downstream, and 93.5 percent at the outfall site. There were slightly fewer caddisfly taxa at the control station (4) compared to the outfall (6) and downstream (7) sites. Unlike Hester-Dendy samplers, in which *Hydropsyche* was consistently the dominant genus within the family Hydropsychidae, *Potamyia flava* tended to be the dominant hydropsychid caddisfly among rock basket samples.

Except for a single individual Empididae larva found in the control station subsample, the order Diptera was represented entirely by chironomids. The genera *Polypedilum* and *Rheotanytarsus* combined made up 85.6 percent of chironomids at the downstream station, 53.6 percent at the outfall, and 88.6 percent at the control site. The number of chironomid taxa was similar at the downstream (12) and control (13) stations but was slightly lower at the outfall (10) site. Chironomids made up a similar percentage of subsamples at all three stations.

Table 11. Missouri River Macroinvertebrate Composition: Rock Basket Samples Percent Dominant Taxa

↓Variable	Station→	control	outfall	downstream
Avg. TR		26.3	13.7	26.0
Avg. Number EPTT		10.0	5.7	10.3
% Ephemeroptera		4.2	13.5	4.3
% Plecoptera		0.3	0.5	0.3
% Trichoptera		74.9	56.3	74.8
% Dominant Families				
Hydropsychidae		74.9	52.6	74.4
Chironomidae		19.9	21.4	18.2
Caenidae		2.6	12.0	3.4
Corbiculidae		0.2	2.1	0.8
Argia		0.1	2.6	0.8
Heptageniidae		0.8	0.5	0.7
Perlidae		0.3	0.5	0.3
Baetidae		0.5	0.5	0.3
Leptoceridae		0.0	2.6	0.2
Polycentropodidae		0.0	1.0	0.1
Gomphidae		0.1	2.1	0.1
Tubificidae		0.0	1.6	0.1
Leptohyphidae		0.0	0.5	0.0
Isonychiidae		0.3	0.0	<0.1

The number of mayfly taxa was distributed similarly among sites, with the highest being at the control (7) and the lowest at the outfall station (5). The family Caenidae was the dominant mayfly family found in rock baskets, making up between 60.6 and 88.5 percent of mayflies. Individuals of *Amercaenis* and *Caenis hilaris* were the only two taxa representing this family. Heptageniid mayflies also were consistently present in these samples but in much lower numbers compared to Caenidae. Mayflies made up a higher percentage of the outfall sample than either the downstream or control samples. The downstream and control sites each had just over 4 percent of the sample made up of mayflies, whereas the outfall station had 13.5 percent mayflies.

Stoneflies were present in low abundance, and no more than two stonefly taxa were present in any of the rock basket samples. With 16 *Neoperla* individuals, the control station had the highest number of stoneflies of any of the three sample sites.

Rock basket samples had a similar assortment of relatively rare taxa groups as the Hester-Dendy samples (i.e., dragonflies and damselflies, aquatic worms, fingernail clams, Asian clams, snails, and water mites). In addition, however, rock baskets also included a freshwater mussel (Unionidae) at the downstream station and an immature crayfish (*Orconectes* sp.) at the outfall site.

7.4 Quantitative Similarity Index.

QSI values were calculated for both Hester-Dendy and rock basket samples to determine the degree of macroinvertebrate community differences among stations (Table 12). Among Hester-Dendy samples, the highest QSI value (89.8) occurred when comparing the downstream station with the outfall station. QSI values were much lower when comparing the control station with the outfall (QSI=76.8) and downstream (QSI=75.4) stations. For rock basket samples, the highest QSI value occurred when comparing the downstream station with the control (QSI=93.3). When comparing the outfall station with either the control (QSI=63.3) or the downstream stations (QSI=67.5), the values were much lower.

Table 12. QSI Values Using Hester-Dendy (HD) and Rock Basket (RB) Samplers

	QSI (percent)	
Stations	HD	RB
control vs. outfall	76.8	63.3
control vs. downstream	75.4	93.3
outfall vs. downstream	89.8	67.5

8.0 Discussion

8.1 Physicochemical Data

8.1.1 Missouri River Gaging Station Data

Although river stage fell by about five feet after macroinvertebrate samplers and data sondes were deployed, all of the equipment remained submerged for the duration of the study. Because the riverbank at the upstream control station had a lesser slope, the Hester-Dendy arrays were in shallower water. Over the course of the deployment period, they also had moved closer to the bank compared to the other stations. The lower river stage also altered the flow pattern at the upstream portion of the outfall station. A rock outcropping that may have been a small wing dike just upstream of the discharge pipe resulted in an eddy current for roughly one-third the length of the station. At the higher stage, neither the wing dike nor the eddy current was visible.

8.1.2 Water Quality Field Parameter and Data Sonde Analysis

Data sonde and water quality field parameters tended to support one another. Depending on the parameter in question, effluent samples sometimes had very different properties than control station samples. Many of the parameters sampled, however, showed little change in the Missouri River blending reach despite the influx of water from the Jefferson City Plant.

Although turbidity was extremely high in each of the effluent types, the softening basin blowdown resulted in the highest readings in the river itself. Based on visual observations at the study site, it appeared as though the particulates in the softening basin effluent remained in suspension much longer than either the sand filter or pre-sedimentation effluents. This observation may have been partially due to its light color making it more apparent than the other effluents. Even after conducting several turbidity dilutions in the laboratory, both pre-

sedimentation and softening basin effluent turbidity exceeded the meter's capacity. It is unknown, therefore, the degree to which one effluent or the other was more turbid. TSS (discussed below) was much higher in the softening basin effluent, which may also contribute to this effluent resulting in higher river turbidity readings than the others. Although sondes at the downstream station recorded turbidity spikes, they tended to be lower than the outfall station, indicating that particles in the effluent either were settling out of suspension or were becoming more dilute as distance from the outfall increased.

As expected, the magnitude of changes in blending reach pH depended on the waste stream type. Although a pH change of 0.1 units in response to softening basin discharge was observed during the August 15, 2013, grab sample trip (Figure 17), most sonde readings tended to record pH increases in the range of 0.2-0.3 units during discharges at the outfall site. The pH readings taken in the blending reach during the four grab sample trips ranged from 0.07 to 0.15 units higher than the control during the softening basin discharge, suggesting that the pH spikes observed in sonde data were from the softening basin effluent. This pH change was observed throughout the sonde deployment period with regularity at both the outfall and downstream stations. However, the magnitude of these changes was lower at the downstream station, likely resulting from a combination of dilution and pH buffering action by the river.

Although no difference in conductivity was observed in the blending reach during water quality grab sampling trips, very small decreases were noted in the sonde readings. The magnitude of these changes (<10 µS/cm) was such that they could have been attributed to instrument drift or minor fluctuations in water chemistry, but the regularity with which these changes occurred indicates that at least one of the effluent types had a slight effect on conductivity in the blending reach. Compared to the other two effluent types, the pre-sedimentation effluent conductivity was only slightly lower than the control. In addition, based on sonde readings taken at known discharge events (Figure 18), both the sand filter and softening basin effluent appear to result in minor conductivity decreases in the blending reach. These effects were not, however, observed at the downstream station, likely due to dilution of the effluent.

Dissolved oxygen concentrations did not exhibit daily fluctuations during the first 7 days of sonde deployment when the river stage was higher. As the river stabilized, however, dissolved oxygen also tended to stabilize with predictable peaks and valleys as dictated by algal production and demands. Days in which dissolved oxygen trended downward (e.g., August 22, September 1, 2013) may have experienced greater cloud cover, which would reduce the oxygen output of aquatic plants and algae. Total solar radiation (megajoules per square meter) at the University of Missouri's Sanborne Field in Columbia, Missouri, was lower during these days of relatively low dissolved oxygen (Missouri Historical Agricultural Weather Database available for query at http://agebb.missouri.edu/weather/history/). Though not a direct measure, total solar radiation does have a strong negative correlation with cloud cover (Liancong et al. 2010).

MAWC's Missouri State Operating Permit (#MO-0004600) requires quarterly monitoring for TRC and includes an Intake and Effluent Characteristics table. Based on the single analysis

included in this table, TRC was reported at 0.7 mg/L, which is slightly higher than all but two of the TRC effluent concentrations in this study. TRC tended to be higher than the control in each of the effluent grab samples; however, the fact that TRC was detected in the upstream control was surprising. Given that even the control samples had TRC concentrations in excess of the chronic TRC standard of 10 µg/L (MDNR 2014), it is possible that some chemical interference with this analysis affected the observed readings (Engelhardt 2013). Turbidity and color of these grab samples also may have affected the results.

8.1.3 Water Quality Chemical Constituent Analysis

A total of 20 metals were analyzed for each of the three effluent types. Although none of the three effluent types yielded metals in concentrations higher than Missouri's Water Quality Standards (MDNR 2014), the concentration of some metals in the effluent samples differed from the control. The pre-sedimentation effluent had four metals (Fe, Al, Mn, and Zn) that were consistently present in higher concentrations than the control, whereas Ca was slightly lower. Given that the pre-sedimentation effluent is nothing more than raw river water with concentrated sediment, it was not expected that there would be any difference in metals between the effluent and the control. Although the process flow diagram in MAWC's operating permit indicates that potassium permanganate ($KMNO_4$) is added prior to the pre-sedimentation basin, this compound is no longer used at the Jefferson City Plant. In addition, other than a cationic polymer, no chemical compounds are added at this stage of treatment (Steve Ridenhour, MAWC, pers. comm.). The reason for the concentrations of manganese, iron, aluminum, and zinc present in the pre-sedimentation effluent, therefore, is unknown. The sand filter and softening basin effluents each had only one metal that was higher than the control (Fe for the sand filter and Cr for the softening basin). The majority of the remaining metals were present either in similar or lower concentrations than the control. Of the metals that had lower concentrations in the effluent, it is likely they were bound to particles released in the effluent. These particles would have been removed by filtering in the field and would therefore not be present for dissolved metals chemical analysis. When analyzing well water samples for metals there is a considerable difference in metals concentrations between filtered and unfiltered samples (Terry Timmons, MDNR Drinking Water Program, pers. comm.), so it is probable that unfiltered effluent samples would yield very different results in drinking water effluent samples as well.

Despite the heavy load of calcium carbonate ($CaCO_3$) and magnesium hydroxide ($Mg(OH)_2$) particulates in the softening basin effluent, hardness levels were much lower than the control. Similarly, hardness levels also were lower in the sand filter effluent. Filtering of samples prior to analysis removed these particulates, which may have had an effect on hardness values. It is also possible that if treated (softened) water is used during the backwash and blowdown process, hardness in the effluent will be lower than the raw river water.

TSS was highest in the softening basin effluent. The lowest TSS concentration in the softening basin effluent was six times higher than the highest pre-sedimentation TSS and 48 times higher than the highest sand filter TSS concentration. This TSS trend, coupled with the observation that

softening basin effluent particulates stay suspended in the water column, is a likely factor in the high sonde turbidity readings recorded for this effluent type.

8.2 Macroinvertebrate Community Assessment

8.2.1 Hester-Dendy Samplers

Despite a seemingly large difference in the mean number of individuals (and, by extension, density), there was no statistically significant difference among stations. It is likely that the high standard deviation within each station's data set resulted in this finding. The number of individuals among replicates in the downstream station's subsample ranged from 416 to 1459, the outfall sample ranged from 150 to 2051, and the control ranged from 710 to 1582. In the case of the outfall station, four of the arrays had roughly similar numbers of individuals in the sample and one outlier had about four times more than the others. Macroinvertebrate density among stations was similarly distributed as mean number of individuals, with densities of the control and downstream stations being similar and the outfall station being lower. Differences in density among stations were not statistically significant, however.

Methods described in other large river monitoring protocols (e.g., Ohio EPA 1989) recommend that control stations and test stations be placed such that ecological conditions are as similar among stations as possible. Because differences in flow can affect the rate of Hester-Dendy macroinvertebrate colonization (New Jersey DEP 2005), velocities also should be similar among stations. Flow conditions present at the outfall station, however, may have affected the colonization rate. The upstream portion of the outfall station had an eddy current that the downstream and control stations did not. The extent to which this current affected macroinvertebrate colonization on the Hester-Dendy sample arrays is unknown, but it could be a confounding factor. Flow conditions at the control and downstream stations were more similar to one another, despite the fact that the control station was somewhat shallower. The number of individuals at the downstream station replicates tended to be more similar to the control compared to the outfall replicates.

Although the number of individuals and density was highest at the control station, TR and density of TR was significantly lower than either the outfall or downstream stations, which were similar to one another. Shallower water depth at the control station may have had some effect on TR by excluding certain taxa that were more sensitive to velocity, wave action, or more direct sunlight. Likewise, the macroinvertebrate community at the control station had a significantly lower SDI than the remaining stations. Lower TR likely contributed at least partly to this difference, which indicates that the control samples were less diverse and evenly distributed than the outfall and downstream stations. Although there were no significant differences in EPTT among stations, the BI value of the outfall station was significantly higher than the control site. This observation indicates that the outfall station has a macroinvertebrate community that is more tolerant of organic pollutants (e.g., wastewater) despite having a similar number of EPTT, which generally tend to be pollution sensitive. The BI value for the downstream station also was higher than the control but not to the extent that the difference was statistically significant. The downstream station's BI value was very slightly lower than the outfall, but additional stations

farther downstream would be needed to determine whether this was indicative of some sort of "recovery" trend.

The macroinvertebrate community composition using Hester-Dendy samplers for this study bore similarities with studies conducted on other large non-wadeable rivers in the Midwest (e.g., Weigel and Dimick 2011), namely an abundance of hydropsychid caddisflies, heptageniid mayflies, and chironomids. These samples also exhibited a trend noted by McCord and Kuhl (2013) that the numbers represented in metrics such as TR and EPTT were largely due to rare taxa that were represented by only a few individuals, whereas relatively few taxa groups accounted for the majority of relative abundance and density measures. Considering the generally sensitive EPTT group, the outfall sample had the lowest percent composition of caddisflies but the highest percentage of mayflies. The downstream and outfall stations also had more mayfly and caddisfly taxa than the control station. Stoneflies were too rare in these samples to make a notable contribution to the assessment. Although differences in community composition existed among stations, there were no consistent trends indicating that stations downstream of the Jefferson City Plant outfall were qualitatively better or worse than the control based on Hester-Dendy sampler information.

8.2.2 Rock Basket Samplers

Unlike the Hester-Dendy samplers, there was a statistically significant difference in the number of individuals among stations using rock baskets. There were significantly more individuals at the control station than either the outfall or downstream station. In addition, the outfall station was significantly different than the downstream as well. The effect of flow patterns on rock basket colonization was particularly acute at the outfall station. The rock basket nearest the outfall (replicate a) was buried in sediment and had only three individuals in the subsample. Although the downstream sampler (replicate c), which had 77 individuals, was covered in silt when it was retrieved, it was not buried. Silt had an obvious and substantial negative effect on rock basket macroinvertebrate colonization.

Given that there were only three individuals in one of the rock basket replicates, TR was also quite low. Because of this outlier, the data were not normally distributed, and the nonparametric Kruskal-Wallis ANOVA on Ranks was required. This test compares median rather than mean values among stations, and the results indicated that there was no statistically significant difference in TR among stations using rock baskets. There were, nevertheless, far fewer taxa at the outfall station than the remaining sites, which was likely attributable to the amount of benthic sediment. The downstream station had nearly identical TR compared to the control site, which suggests that the effects of benthic sediment do not extend into the downstream sample reach. Rock basket EPTT taxa and BI values followed a pattern similar to that observed with the Hester-Dendy samples. Although there was no significant difference in EPTT among stations, the mean among outfall samples was slightly lower than the control or downstream sites. The number of EPTT at the downstream station was nearly the same as the control, which again suggests that whatever factors (e.g., flow, turbidity, sediment) are present at the outfall station do not extend to the downstream site. BI values were significantly higher at the outfall station

compared to both the control and downstream stations, again suggesting that the macroinvertebrate community at this site tends to be more tolerant to organic pollutants. Although the downstream BI value was slightly higher than the control, this difference was not statistically significant and may suggest that the conditions present at the outfall site do not extend far downstream. SDI values were similar among the three stations, which indicate the macroinvertebrate communities were similarly diverse and evenly distributed.

Macroinvertebrate community composition based on rock basket samples exhibited similar trends compared to those of Hester-Dendy samples. When comparing the downstream station with the control, however, the macroinvertebrate community attributes were remarkably similar. The percentage of mayflies and caddisflies were nearly identical between the two sites, as were the percentages of the top three most abundant families. These similarities existed despite the fact that there were approximately half as many individuals in the downstream subsample than the control.

Habitat limitations caused by benthic sediment is the likely cause of the community differences observed at the outfall station, and the rock basket community composition data for this particular station should be viewed with this caveat. As mentioned earlier, at least one of the three rock basket samples at the outfall station was unknowingly deployed in an area with soft benthic sediment that buried the sampler and rendered it less usable for macroinvertebrate colonization. The use of rock baskets in this study allowed for comparing potential differences in colonization rates on the river bottom versus the water column. Benthic sediments had an obvious effect on the ability of macroinvertebrates to access and colonize samplers placed on the river bottom. Although the likely cause in this case was burial of rock baskets, sediment quality in depositional areas behind wing dikes also can affect macroinvertebrate communities (Poulton and Allert 2011). The source and composition of sediment in the study reach and whether it differs from other areas of the Missouri River were beyond the scope of this study; however, future research to address this matter should be considered.

8.3 Quantitative Similarity Index

None of the Hester-Dendy QSI values were below 65 percent, which suggests that macroinvertebrates colonizing in the water column were mostly similar among stations. The lowest QSI values occurred when comparing the control station with the two downstream test stations, whereas the highest value was between the outfall and downstream stations. Although well above the 65 percent threshold, there were slight macroinvertebrate community dissimilarities between the control and test stations when sampling in the water column.

With the rock basket samplers, however, the QSI was slightly below the 65 percent threshold value when comparing the control versus the outfall station. The sedimentation issue at the outfall site described earlier likely had an effect on the QSI calculation between the control and the outfall. However, when comparing the downstream station with the control, the QSI was very high (QSI=93.3), indicating that there is little difference in the macroinvertebrate community between these two stations. The relatively low QSI between the downstream and

outfall stations (QSI=67.5) suggests that the physical/chemical factors present that contributed to the outfall station macroinvertebrate community were localized and were not present in the downstream site.

There were differences in QSI distribution between the two sampling types. Whereas the highest rock basket QSI occurred when comparing the downstream versus control stations, this comparison yielded the lowest QSI for Hester-Dendy samplers. Much of this difference can be attributed to the differential colonization rates and biological metrics (TR, etc.) between sample types and among stations. It is apparent that placing samplers in the water column versus the river bottom can yield different macroinvertebrate community results.

9.0 Conclusions

Each of the objectives of this study was accomplished, with the exception that no drift samples were collected from the Missouri River. Water quality was assessed via *in situ* measurements, surface water grab samples for chemical analysis, and continuous monitoring with data sondes. The macroinvertebrate community was assessed by deploying five Hester-Dendy arrays and three rock baskets at each of the three stations.

Testing of the null hypotheses yielded the following results.

1) Control station and test station water quality parameters collected by data sondes exhibited differences.

2) Differences existed when comparing certain *in situ* water chemistry parameters between the downstream and the upstream control stations. Differences also existed among stations in some water quality parameters submitted for laboratory chemical analysis.

3) The number of individuals and density of the macroinvertebrate assemblage colonizing Hester-Dendy samplers was not significantly different among stations. Statistical analysis of biological metrics, however, was variable. Significant differences were observed in TR, BI, and SDI among stations. There was no significant difference in the number or density of EPTT.

4) Statistically significant differences in the total number of individuals collected in rock basket samples existed among stations. Significant differences were observed in BI values. The remaining biological metrics (TR, EPTT, and SDI) showed no significant differences among stations.

10.0 Summary

As stated in Section 4.0, the goal of this study was to determine whether a difference exists in the Missouri River water chemistry or macroinvertebrate community upstream versus downstream from the Jefferson City Plant's outfall. The following points address the various water chemistry and macroinvertebrate community findings of this study.

1. River stage was higher during macroinvertebrate sampler and data sonde deployment than the remainder of the study and masked a small wing dike and eddy current at the outfall test station. This eddy current is likely to have had at least some effect on macroinvertebrate colonization.

2. *In situ* water quality measurements were collected from the outfall and two Missouri River stations for each of the three Jefferson City Plant effluent types--pre-sedimentation, sand filter, and softening basin.

3. Turbidity in the pre-sedimentation and softening basin effluent samples were beyond the 1000 NTU meter limit. Turbidity for the sand filter effluent also was much higher than the control but within readable levels.

4. Each of the three effluent types tended to have much higher turbidity and at least somewhat higher pH and lower conductivity compared to the control. Dissolved oxygen was higher than the control in each of the pre-sedimentation and sand filter effluent samples. This trend was not consistently observed with the softening basin effluent. Temperature was nearly the same between control and test stations.

5. Missouri River *in situ* water quality changes in response to Jefferson City Plant effluent was variable and depended on the effluent type. Softening basin effluent tended to have the largest effect on Missouri River turbidity and pH.

6. Water quality data sondes recorded pH, turbidity, conductivity, dissolved oxygen, and temperature for the duration of the macroinvertebrate sampler deployment period.

7. Data sondes recorded consistent turbidity and pH spikes associated with effluent discharge at the outfall and downstream stations. The magnitude of these spikes was lower at the downstream station. Conductivity showed a pattern of slight decreases at the outfall station but not at the downstream site. No difference among stations was observed in dissolved oxygen and temperature patterns using data sondes.

8. Pre-sedimentation effluent tended to have more species of dissolved metals that were higher than the control compared to the other two effluent types. Sand filter and softening basin effluent had mostly lower concentrations of dissolved metals than the control. The filtering process necessary for dissolved metals analysis likely removed particles to which metals were adsorbed.

9. None of the dissolved metals tested occurred in concentrations that exceeded Missouri's Water Quality Standards.

10. Sand filter and softening basin effluent hardness levels were much lower than the control; however, pre-sedimentation effluent was roughly the same as the control.

11. TSS concentrations were highest in the softening basin effluent, followed by pre-sedimentation and sand filter effluents.

12. Although there were no statistically significant differences among stations in the total number of individuals or density in Hester-Dendy samples, there were differences in TR, BI, and SDI. The control station had significantly lower values for these metrics than at least one of the test stations, suggesting that upstream control conditions favored a less diverse and evenly distributed macroinvertebrate community.

13. The upstream control station had a significantly higher number of macroinvertebrates in rock basket samples than both test stations. The outfall rock baskets were covered in benthic fine sediment, which may have contributed to the significantly lower number than the remaining stations. The upstream control and downstream rock baskets were not covered with benthic fine sediment, further suggesting that benthic fine sediment was a contributor to the lower numbers at the outfall. Although TR, EPTT, and SDI all were lower in outfall rock basket samples, there were no significant differences among sites for these metrics. There were significant differences in the BI metric between the control and the outfall, with the outfall being higher.

14. Hester-Dendy samplers were colonized primarily by hydropsychid caddisflies, heptageniid mayflies, and chironomids. The control station had the fewest mayfly taxa, whereas the outfall and downstream stations were similar. Although the control station also had the fewest caddisfly taxa, this group made up a higher percentage at this site than the test stations.

15. Rock basket samplers were colonized primarily by hydropsychid caddisflies and chironomids, but the percentage of heptageniid mayflies was much lower compared to Hester-Dendy samples. The outfall station had very few individuals in rock basket subsamples due to two of the three samplers being at least partially buried in fine sediment. The macroinvertebrate community that colonized rock baskets in the downstream test station was very similar to the control site.

16. The QSI was greater than the 65 percent impairment threshold for all station comparisons using Hester-Dendy samplers. The highest QSI value for Hester-Dendy samples occurred when comparing the two test stations with one another. When comparing the control station with the two test stations, QSI values were nearly the same.

17. For rock basket samples, the QSI value was below the 65 percent threshold when comparing the control with the outfall station. With a QSI value of 93.3 percent, there was very little difference between the control and downstream rock basket samples.

11.0 Recommendations

1. In any future macroinvertebrate studies for this facility, an upstream control station with flow conditions similar to the backwater eddy at the outfall site should be carefully selected to assess

these effects. This additional control site would determine the degree to which a depositional flow pattern affects the macroinvertebrate community structure.

2. Although total recoverable iron is a component of the Jefferson City Plant's operating permit, it is the dissolved metals fraction that is listed in Missouri's Water Quality Standards. It was for this reason that dissolved metals were analyzed for this study. Total recoverable metals analysis of the three effluent types should be examined in future studies. Questions raised in this study regarding the reduction of certain metals during filtering for dissolved metals analysis would be addressed by total recoverable metals analysis.

3. A study should be conducted to characterize the chemical composition, including total recoverable metals, of benthic sediments in the eddy current downstream of the outfall. This analysis should then be compared to the chemical character of sediments collected from an upstream dike pool with a similar flow pattern (e.g., the control site mentioned in the first recommendation).

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Appendix A

Summer 2013 Missouri River Macroinvertebrate Taxa Lists

Hester-Dendy Sample Data

Rock Basket Sample Data

Aquid Invertebrate Database Bench Sheet Report
Missouri R [132032], Station #1a, Sample Date: 9/9/2013 9:35:00 AM
HD = Hester-Dendy; -99 = Presence

ORDER: TAXA	HD
DIPTERA	
Cladotanytarsus	3
Labrundinia	1
Nanocladius	1
Polypedilum flavum	49
Polypedilum scalaenum grp	24
Rheotanytarsus	73
Tanytarsus	6
Telopelopia	1
Thienemannimyia grp.	6
Tribelos	6
EPHEMEROPTERA	
Amercaenis	5
Caenis hilaris	14
Heptageniidae	7
Hexagenia limbata	1
Isonychia bicolor	6
Isonychia sicca	2
Maccaffertium mexicanum integrum	20
Pseudocloeon	3
Stenacron	1
Tricorythodes	1
ODONATA	
Argia	2
Gomphus	5
Neurocordulia	2
PLECOPTERA	
Acroneuria	1
Neoperla	3
TRICHOPTERA	
Hydropsyche	192
Hydropsychidae	59
Nectopsyche	1
Potamyia flava	84
TRICLADIDA	
Planariidae	3
VENEROIDA	
Corbicula	1

Aquid Invertebrate Database Bench Sheet Report
Missouri R [132033], Station #1b, Sample Date: 9/9/2013 9:28:00 AM
HD = Hester-Dendy; -99 = Presence

ORDER: TAXA	HD
BASOMMATOPHORA	
Ancylidae	1
DIPTERA	
Cladotanytarsus	1
Harnischia	1
Nanocladius	1
Polypedilum flavum	99
Polypedilum scalaenum grp	28
Rheotanytarsus	190
Stenochironomus	1
Tanytarsus	14
Telopelopia	4
Thienemannimyia grp.	6
EPHEMEROPTERA	
Amercaenis	12
Caenis hilaris	21
Isonychia bicolor	13
Isonychia sicca	12
Maccaffertium mexicanum integrum	102
Pseudocloeon	58
Tricorythodes	1
ODONATA	
Argia	1
Gomphus	1
Neurocordulia	5
PLECOPTERA	
Neoperla	1
TRICHOPTERA	
Hydropsyche	258
Hydropsychidae	170
Nectopsyche	1
Neureclipsis	1
Potamyia flava	126
TRICLADIDA	
Planariidae	23
TUBIFICIDA	
Tubificidae	2
VENEROIDA	
Corbicula	3

Aquid Invertebrate Database Bench Sheet Report
Missouri R [132034], Station #1c, Sample Date: 9/9/2013 9:20:00 AM
HD = Hester-Dendy; -99 = Presence

ORDER: TAXA	HD
DIPTERA	
Cladotanytarsus	2
Corynoneura	1
Labrundinia	1
Polypedilum flavum	56
Polypedilum scalaenum grp	11
Rheotanytarsus	118
Tanytarsus	5
Telopelopia	1
Thienemanniella	2
Thienemannimyia grp.	3
Tribelos	4
EPHEMEROPTERA	
Amercaenis	19
Caenis hilaris	13
Isonychia bicolor	7
Isonychia sicca	5
Maccaffertium mexicanum integrum	55
Pseudocloeon	9
ODONATA	
Neurocordulia	2
PLECOPTERA	
Acroneuria	-99
Attaneuria ruralis	2
TRICHOPTERA	
Hydropsyche	257
Hydropsychidae	113
Nectopsyche	1
Neotrichia	1
Neureclipsis	2
Potamyia flava	40
VENEROIDA	
Corbicula	1

Aquid Invertebrate Database Bench Sheet Report
Missouri R [132035], Station #1d, Sample Date: 9/9/2013 9:17:00 AM
HD = Hester-Dendy; -99 = Presence

ORDER: TAXA	HD
"HYDRACARINA"	
Acarina	1
DIPTERA	
Labrundinia	1
Polypedilum flavum	48
Polypedilum scalaenum grp	7
Rheotanytarsus	38
Tanytarsus	4
Telopelopia	2
Thienemannimyia grp.	2
Tribelos	2
EPHEMEROPTERA	
Amercaenis	3
Caenis hilaris	10
Isonychia bicolor	3
Isonychia sicca	5
Maccaffertium mexicanum integrum	40
Pseudocloeon	22
Stenonema femoratum	1
ODONATA	
Argia	1
Neurocordulia	-99
PLECOPTERA	
Acroneuria	-99
Attaneuria ruralis	-99
TRICHOPTERA	
Hydropsyche	149
Hydropsychidae	48
Neureclipsis	2
Potamyia flava	24
TRICLADIDA	
Planariidae	1
VENEROIDA	
Pisidiidae	2

Aquid Invertebrate Database Bench Sheet Report
Missouri R [132036], Station #1e, Sample Date: 9/9/2013 9:11:00 AM
HD = Hester-Dendy; -99 = Presence

ORDER: TAXA	HD
BASOMMATOPHORA	
Ancylidae	1
DIPTERA	
Cladotanytarsus	2
Hemerodromia	1
Labrundinia	1
Paralauterborniella	1
Polypedilum flavum	96
Polypedilum scalaenum grp	20
Rheotanytarsus	247
Stenochironomus	1
Tanytarsus	9
Telopelopia	2
Thienemannimyia grp.	13
Tribelos	2
EPHEMEROPTERA	
Amercaenis	16
Caenis hilaris	12
Isonychia bicolor	5
Isonychia sicca	4
Maccaffertium mexicanum integrum	82
Pseudocloeon	63
ODONATA	
Argia	2
Gomphidae	-99
Neurocordulia	5
PLECOPTERA	
Acroneuria	3
TRICHOPTERA	
Cheumatopsyche	1
Hydropsyche	472
Hydropsychidae	261
Neureclipsis	3
Potamyia flava	132
TRICLADIDA	
Planariidae	2

Aquid Invertebrate Database Bench Sheet Report
Missouri R [132037], Station #2a, Sample Date: 9/9/2013 10:03:00 AM
HD = Hester-Dendy; -99 = Presence

ORDER: TAXA	HD
DIPTERA	
Ablabesmyia	2
Glyptotendipes	1
Polypedilum flavum	31
Polypedilum halterale grp	2
Polypedilum scalaenum grp	10
Rheotanytarsus	42
Stenochironomus	3
Tanytarsus	10
Thienemannimyia grp.	4
Tribelos	1
EPHEMEROPTERA	
Amercaenis	10
Caenis hilaris	11
Isonychia bicolor	2
Isonychia sicca	2
Maccaffertium mexicanum integrum	19
Pseudocloeon	11
ODONATA	
Argia	6
Gomphus	1
Neurocordulia	5
TRICHOPTERA	
Hydropsyche	66
Hydropsychidae	60
Nectopsyche	5
Potamyia flava	40

Aquid Invertebrate Database Bench Sheet Report
Missouri R [132038], Station #2b, Sample Date: 9/9/2013 9:58:00 AM
HD = Hester-Dendy; -99 = Presence

ORDER: TAXA	**HD**
DIPTERA	
Ablabesmyia	2
Cladotanytarsus	1
Hemerodromia	1
Labrundinia	1
Nanocladius	1
Polypedilum flavum	5
Rheotanytarsus	8
Tanytarsus	2
Thienemannimyia grp.	3
Tribelos	1
EPHEMEROPTERA	
Amercaenis	2
Caenis hilaris	8
Isonychia bicolor	1
Maccaffertium mexicanum integrum	46
Pseudocloeon	1
ODONATA	
Argia	2
Gomphus	1
Hagenius brevistylus	-99
Neurocordulia	3
TRICHOPTERA	
Hydropsyche	21
Hydropsychidae	15
Nectopsyche	3
Potamyia flava	22

Aquid Invertebrate Database Bench Sheet Report
Missouri R [132039], Station #2c, Sample Date: 9/9/2013 9:56:00 AM
HD = Hester-Dendy; -99 = Presence

ORDER: TAXA	HD
DIPTERA	
Cladotanytarsus	1
Polypedilum flavum	52
Polypedilum scalaenum grp	14
Rheotanytarsus	62
Tanytarsus	2
Telopelopia	1
Thienemannimyia grp.	5
Tribelos	1
EPHEMEROPTERA	
Amercaenis	14
Caenis hilaris	11
Heptageniidae	1
Isonychia sicca	2
Maccaffertium mexicanum integrum	55
Pseudocloeon	13
ODONATA	
Argia	1
Neurocordulia	2
TRICHOPTERA	
Hydropsyche	95
Hydropsychidae	54
Neureclipsis	2
Potamyia flava	55

Aquid Invertebrate Database Bench Sheet Report
Missouri R [132040], Station #2d, Sample Date: 9/9/2013 9:50:00 AM
HD = Hester-Dendy; -99 = Presence

ORDER: TAXA	HD
DIPTERA	
Ablabesmyia	2
Labrundinia	3
Nanocladius	1
Polypedilum flavum	37
Polypedilum illinoense grp	2
Polypedilum scalaenum grp	11
Rheotanytarsus	37
Tanytarsus	6
Telopelopia	2
Thienemannimyia grp.	7
Tribelos	5
EPHEMEROPTERA	
Amercaenis	21
Caenis hilaris	14
Isonychia bicolor	3
Isonychia sicca	1
Maccaffertium mexicanum integrum	45
Pseudocloeon	7
Tricorythodes	2
ODONATA	
Argia	3
Neurocordulia	5
PLECOPTERA	
Attaneuria ruralis	-99
Neoperla	2
TRICHOPTERA	
Hydropsyche	163
Hydropsychidae	86
Nectopsyche	1
Neureclipsis	2
Potamyia flava	72

Aquid Invertebrate Database Bench Sheet Report
Missouri R [132041], Station #2e, Sample Date: 9/9/2013 9:57:00 AM
HD = Hester-Dendy; -99 = Presence

ORDER: TAXA	HD
"HYDRACARINA"	
Acarina	1
DIPTERA	
Cladotanytarsus	1
Hemerodromia	1
Polypedilum flavum	174
Polypedilum scalaenum grp	3
Rheotanytarsus	575
Tanytarsus	5
Thienemanniella	3
Thienemannimyia grp.	1
Tribelos	3
EPHEMEROPTERA	
Amercaenis	30
Caenis hilaris	3
Hexagenia limbata	1
Isonychia bicolor	6
Isonychia sicca	5
Maccaffertium mexicanum integrum	98
Pseudocloeon	137
Tricorythodes	1
ODONATA	
Neurocordulia	3
PLECOPTERA	
Acroneuria	-99
Neoperla	2
TRICHOPTERA	
Hydropsyche	585
Hydropsychidae	336
Nectopsyche	1
Neotrichia	1
Neureclipsis	4
Potamyia flava	70
VENEROIDA	
Corbicula	1

Aquid Invertebrate Database Bench Sheet Report
Missouri R [132042], Station #3a, Sample Date: 9/9/2013 10:54:00 AM
HD = Hester-Dendy; -99 = Presence

ORDER: TAXA	HD
"HYDRACARINA"	
Acarina	1
DIPTERA	
Hemerodromia	1
Labrundinia	1
Polypedilum flavum	93
Polypedilum scalaenum grp	1
Rheotanytarsus	518
Tanytarsus	4
Thienemanniella	2
Thienemannimyia grp.	4
EPHEMEROPTERA	
Amercaenis	9
Isonychia bicolor	9
Isonychia sicca	6
Maccaffertium mexicanum integrum	24
Pseudocloeon	65
MEGALOPTERA	
Corydalus	1
ODONATA	
Argia	-99
PLECOPTERA	
Perlesta	1
TRICHOPTERA	
Hydropsyche	469
Hydropsychidae	196
Neureclipsis	2
Potamyia flava	11

Aquid Invertebrate Database Bench Sheet Report
Missouri R [132043], Station #3b, Sample Date: 9/9/2013 10:47:00 AM
HD = Hester-Dendy; -99 = Presence

ORDER: TAXA	HD
DIPTERA	
Ablabesmyia	1
Polypedilum flavum	46
Polypedilum scalaenum grp	1
Rheotanytarsus	76
Tribelos	1
EPHEMEROPTERA	
Amercaenis	5
Caenis hilaris	1
Isonychia bicolor	7
Isonychia sicca	8
Maccaffertium mexicanum integrum	28
Pseudocloeon	68
ODONATA	
Neurocordulia	1
PLECOPTERA	
Attaneuria ruralis	1
Neoperla	2
TRICHOPTERA	
Hydropsyche	314
Hydropsychidae	113
Potamyia flava	35
TRICLADIDA	
Planariidae	1
VENEROIDA	
Corbicula	1

Aquid Invertebrate Database Bench Sheet Report
Missouri R [132045], Station #3d, Sample Date: 9/9/2013 10:39:00 AM
HD = Hester-Dendy; -99 = Presence

ORDER: TAXA	HD
DIPTERA	
Polypedilum flavum	57
Rheotanytarsus	130
EPHEMEROPTERA	
Amercaenis	1
Isonychia bicolor	6
Isonychia sicca	4
Maccaffertium mexicanum integrum	18
Pseudocloeon	130
ODONATA	
Neurocordulia	-99
PLECOPTERA	
Attaneuria ruralis	6
TRICHOPTERA	
Hydropsyche	861
Hydropsychidae	353
Potamyia flava	16

Aquid Invertebrate Database Bench Sheet Report
Missouri R [132023], Station #1a, Sample Date: 9/9/2013 9:32:00 AM
RB = Rock Basket; -99 = Presence

ORDER: TAXA	RB
BASOMMATOPHORA	
Ancylidae	1
DIPTERA	
Ablabesmyia	1
Dicrotendipes	1
Labrundinia	1
Nanocladius	2
Polypedilum flavum	24
Polypedilum scalaenum grp	10
Rheotanytarsus	17
Tanytarsus	9
Telopelopia	2
Thienemannimyia grp.	3
EPHEMEROPTERA	
Amercaenis	4
Caenis hilaris	8
Maccaffertium mexicanum integrum	4
ODONATA	
Argia	6
Gomphus	3
Neurocordulia	2
PLECOPTERA	
Neoperla	1
TRICHOPTERA	
Hydropsyche	6
Nectopsyche	1
Neureclipsis	2
Oecetis	1
Potamyia flava	161
TUBIFICIDA	
Tubificidae	4
VENEROIDA	
Corbicula	12
Pisidiidae	1

Aquid Invertebrate Database Bench Sheet Report
Missouri R [132024], Station #1b, Sample Date: 9/9/2013 9:25:00 AM
RB = Rock Basket; -99 = Presence

ORDER: TAXA	RB
DIPTERA	
Ablabesmyia	2
Labrundinia	2
Nanocladius	3
Polypedilum flavum	64
Polypedilum scalaenum grp	19
Rheotanytarsus	96
Tanytarsus	7
Telopelopia	4
Thienemannimyia grp.	10
EPHEMEROPTERA	
Amercaenis	11
Caenis hilaris	21
Heptageniidae	5
Isonychia sicca	1
Pseudocloeon	2
MEGALOPTERA	
Corydalus	-99
ODONATA	
Argia	7
Gomphidae	1
Neurocordulia	2
PLECOPTERA	
Neoperla	1
TRICHOPTERA	
Hydropsyche	126
Hydropsychidae	107
Nectopsyche	2
Neureclipsis	2
Oecetis	1
Potamyia flava	336
VENEROIDA	
Corbicula	6
Pisidiidae	1

Aquid Invertebrate Database Bench Sheet Report
Missouri R [132025], Station #1c, Sample Date: 9/9/2013 9:06:00 AM
RB = Rock Basket; -99 = Presence

ORDER: TAXA	RB
COLEOPTERA	
Stenelmis	1
DIPTERA	
Cladotanytarsus	1
Labrundinia	2
Nanocladius	2
Polypedilum flavum	65
Polypedilum illinoense grp	1
Polypedilum scalaenum grp	4
Rheotanytarsus	108
Tanytarsus	2
Telopelopia	3
Thienemannimyia grp.	10
EPHEMEROPTERA	
Amercaenis	28
Caenis hilaris	16
Heptageniidae	8
Pseudocloeon	5
ODONATA	
Argia	8
Neurocordulia	2
PLECOPTERA	
Acroneuria	1
Neoperla	6
TRICHOPTERA	
Hydropsyche	251
Hydropsychidae	288
Nectopsyche	2
Potamyia flava	668
UNIONIDA	
Unionidae	-99
VENEROIDA	
Corbicula	3

Aquid Invertebrate Database Bench Sheet Report
Missouri R [132026], Station #2a, Sample Date: 9/9/2013 10:07:00 AM
RB = Rock Basket; -99 = Presence

ORDER: TAXA	RB
DIPTERA	
Polypedilum illinoense grp	1
TRICHOPTERA	
Hydropsychidae	2

Aquid Invertebrate Database Bench Sheet Report
Missouri R [132027], Station #2b, Sample Date: 9/9/2013 9:54:00 AM
RB = Rock Basket; -99 = Presence

ORDER: TAXA	RB
DECAPODA	
Orconectes	-99
DIPTERA	
Cryptochironomus	1
Nanocladius	2
Polypedilum flavum	3
Polypedilum scalaenum grp	3
Rheotanytarsus	5
Tanytarsus	6
Thienemannimyia grp.	3
EPHEMEROPTERA	
Amercaenis	1
Baetidae	1
Caenis hilaris	6
Heptageniidae	1
Hexagenia limbata	-99
Tricorythodes	1
ODONATA	
Argia	3
Gomphus	4
PLECOPTERA	
Perlidae	1
TRICHOPTERA	
Hydropsyche	10
Hydropsychidae	14
Nectopsyche	2
Neureclipsis	2
Potamyia flava	40
VENEROIDA	
Corbicula	3

Aquid Invertebrate Database Bench Sheet Report
Missouri R [132028], Station #2c, Sample Date: 9/9/2013 9:43:00 AM
RB = Rock Basket; -99 = Presence

ORDER: TAXA	RB
DIPTERA	
Cladotanytarsus	4
Cryptochironomus	1
Polypedilum flavum	4
Polypedilum halterale grp	1
Polypedilum scalaenum grp	4
Rheotanytarsus	1
Tanytarsus	2
EPHEMEROPTERA	
Caenis hilaris	16
Pentagenia vittigera	-99
ODONATA	
Argia	2
Gomphidae	-99
TRICHOPTERA	
Nectopsyche	3
Potamyia flava	35
TUBIFICIDA	
Limnodrilus udekemianus	1
Tubificidae	2
VENEROIDA	
Corbicula	1

Aquid Invertebrate Database Bench Sheet Report
Missouri R [132029], Station #3a, Sample Date: 9/9/2013 10:50:00 AM
RB = Rock Basket; -99 = Presence

ORDER: TAXA	RB
COLEOPTERA	
Stenelmis	1
DIPTERA	
Ablabesmyia	2
Cryptochironomus	1
Dicrotendipes	1
Harnischia	2
Labrundinia	1
Nanocladius	3
Polypedilum flavum	102
Polypedilum scalaenum grp	9
Rheotanytarsus	79
Tanytarsus	3
Telopelopia	5
Thienemannimyia grp.	15
EPHEMEROPTERA	
Amercaenis	48
Caenis hilaris	9
Heptageniidae	12
Isonychia bicolor	2
Pseudocloeon	8
MEGALOPTERA	
Corydalus	3
ODONATA	
Argia	2
Neurocordulia	5
PLECOPTERA	
Neoperla	7
TRICHOPTERA	
Hydropsyche	456
Hydropsychidae	279
Potamyia flava	542
VENEROIDA	
Corbicula	1

Aquid Invertebrate Database Bench Sheet Report
Missouri R [132030], Station #3b, Sample Date: 9/9/2013 10:44:00 AM
RB = Rock Basket; -99 = Presence

ORDER: TAXA	RB
DIPTERA	
Ablabesmyia	2
Corynoneura	2
Cryptochironomus	3
Dicrotendipes	2
Harnischia	1
Labrundinia	1
Nanocladius	5
Polypedilum flavum	132
Polypedilum scalaenum grp	25
Rheotanytarsus	323
Tanytarsus	16
Telopelopia	14
Thienemannimyia grp.	15
EPHEMEROPTERA	
Amercaenis	47
Caenis hilaris	2
Isonychia bicolor	3
Isonychia sicca	4
Maccaffertium mexicanum integrum	19
Pseudocloeon	9
ODONATA	
Argia	3
Gomphus	1
Ischnura	1
Neurocordulia	5
PLECOPTERA	
Neoperla	4
TRICHOPTERA	
Hydropsyche	154
Hydropsychidae	246
Potamyia flava	926
VENEROIDA	
Corbicula	6

Aquid Invertebrate Database Bench Sheet Report
Missouri R [132031], Station #3c, Sample Date: 9/9/2013 10:32:00 AM
RB = Rock Basket; -99 = Presence

ORDER: TAXA	RB
DIPTERA	
Dicrotendipes	1
Hemerodromia	1
Labrundinia	3
Nanocladius	1
Polypedilum flavum	132
Polypedilum scalaenum grp	9
Rheotanytarsus	174
Tanytarsus	9
Telopelopia	2
Thienemannimyia grp.	17
EPHEMEROPTERA	
Amercaenis	22
Caenis hilaris	15
Isonychia bicolor	5
Isonychia sicca	3
Maccaffertium mexicanum integrum	16
Pseudocloeon	12
ODONATA	
Argia	2
Gomphus	3
Neurocordulia	4
PLECOPTERA	
Neoperla	5
TRICHOPTERA	
Hydropsyche	243
Hydropsychidae	427
Oecetis	2
Potamyia flava	922
VENEROIDA	
Corbicula	2

Appendix B

June 6, 2013 Biological Assessment Study Proposal

Missouri Department of Natural Resources
Biological Assessment Study Proposal
Effects of Drinking Water Treatment Facility Back Wash
Location: Missouri River at Jefferson City, Missouri
June 6, 2013

Objectives

It is presently permissible in the State of Missouri for drinking water treatment facilities located along the Missouri and Mississippi rivers to discharge back wash wastes directly back into the river. Depending on the capacity and design of the facility and its outfall, this effluent can cause a noticeable plume that has a much lighter color than the receiving waters. Whether these plumes have a negative effect on the riverine ecosystem is unknown. We propose, therefore, to collect water chemistry and biological information to aid the WPP's Industrial Permits Unit in updating permits of drinking water treatment facilities whose source and receiving system is the Missouri River.

Our objectives are to: 1) deploy automated data sondes capable of collecting temperature (°C), dissolved oxygen (mg/L), pH (standard units), turbidity (NTU), and conductivity (µS/cm) both within and upstream of a selected plume; 2) collect *in situ* field water quality measurements (pH, conductivity, dissolved oxygen, temperature, and turbidity) during times when data sondes are maintained and aquatic macroinvertebrate samplers are deployed/retrieved; 3) collect water quality grab samples for laboratory analysis of total dissolved metals, TRC and TSS; 4) compare the macroinvertebrate community within the Jefferson City drinking water treatment facility back wash plume with that of the river reach immediately upstream of the discharge; 5) collect macroinvertebrate drift samples using a towed plankton net within the plume and immediately upstream.

Null Hypotheses

1) Water quality parameters collected by data sondes will not differ between the test station(s) and the upstream control.

2) *In situ* water chemistry parameters will not differ between the test station(s) and the upstream control.

3) The macroinvertebrate assemblages colonizing multiple-plate samplers will not differ between the test station(s) and the upstream control.

4) The abundance and taxa composition of drifting macroinvertebrates will not differ between the test station(s) and the upstream control.

Background

Facilities designed to treat raw water collected from rivers, reservoirs, and groundwater for human consumption must remove harmful and distasteful contaminants to meet minimum state and federal drinking water standards. In the case of the Jefferson City drinking water treatment facility, three components of treatment lead to a practice known as "back washing" or "blow down." These include: 1) pre-sedimentation treatment, which is the first stage of the process

and is designed to remove river sediments through the use of gravity; 2) filtration, in which water is passed through a barrier to remove additional solids; and 3) softening, which includes the addition of lime (calcium carbonate, $CaCO_3$) and other chemical constituents in the latter stages of treatment. Back washing can take the form of forcing water or compressed air in the opposite direction of normal intake, either with or without the use of chemicals to facilitate the cleaning process. The water resulting from back washing can be recycled and refined into drinking water, sent to a wastewater treatment facility, or discharged into the system from which the raw water came. This latter alternative is currently used by the Jefferson City facility. The State of Missouri is gathering data to determine the extent to which permit limits should be set to regulate this process waste water.

This study is designed to determine whether differences exist in certain Missouri River water chemistry parameters and the aquatic macroinvertebrate community resulting from Jefferson City treatment facility back wash water. Because this facility has relatively low flow discharges, future studies to evaluate larger facilities that use different treatment processes may be necessary.

Study Design

General: The Missouri American Water's Jefferson City drinking water treatment plant is located on West Main Street in Jefferson City, Missouri and uses surface water of the Missouri River as its source. The water intake is located on the river bed approximately 700 feet from the right descending (south) bank upstream of the Highway 54/63 bridge (Figure 1 and Figure 2). The outfall is also on the right descending bank and discharges onto a substrate of rip rap and river sediment. The Missouri River at this point is a 15^{th} order river, with a mean annual discharge of roughly 69,000 cfs as measured by the USGS gaging station at Boonville, Missouri (gage #06909000).

The three treatment components requiring back washing combine to use approximately 250,000 gallons of water per day at the Jefferson City facility. Filter back washing occurs on an as as-needed basis, depending on the condition of the filters. Pre-sedimentation and softening basin back washing each occur at three intervals during the course of a day. Of the three back wash types, the softening basin back wash results in the most visible plume in the Missouri River and will be used to aid in the placement of macroinvertebrate sampling arrays and collection of water chemistry grab samples.

Biological Sampling: Macroinvertebrate samples will be collected in two to three locations, depending on the length of the plume. Stations upstream and immediately downstream of the discharge point will be surveyed in any case. If the extent of the plume is greater than 1 km, an additional station near the end of the plume will be surveyed. The location of this station will be determined by the measurement of water chemistry parameters or visual inspection of the river. The end of the plume will be considered to be where water chemistry values are similar to those measured upstream of the discharge point. If there are no measureable differences in *in situ* water chemistry parameters relative to the outfall, then the downstream end of the plume will be considered where effluent is no longer visually observable. If the third station is necessary, it will be within the plume near its downstream boundary.

Samples will be collected using round multiple-plate artificial substrate samplers similar to Hester and Dendy (1962). Five replicate arrays will be used at each station. An array will consist of: 1) an anchor; 2) a PVC tube with 3 Hester-Dendy units attached; and 3) two floating marker buoys (see Figure 3). The following description is a modification by DeShon (1995) of the original Hester-Dendy design. Each Hester-Dendy unit will consist of eight 3-inch diameter Masonite plates on a 3-inch long ¼-inch diameter eyebolt. For each sampler, there will be three single spacings, three double spacings, and one triple space between the plates [i.e. 1/8" between 3 plate pairs, 1/4" (3 plates), and 3/8" (1 plate)] (similar to Figure 4). The colonizable surface area for each three Hester-Dendy sample array (= replicate) is approximately 3 ft^2.

Artificial substrates will be set in the period between June 15 and September 30 and retrieved after approximately 30 days. Arrays will be attached to nearshore structures and instream anchors using coated aluminum cable. During retrieval, samples will be pulled from the water carefully to minimize macroinvertebrate loss and then transferred to a sieve bucket or ponar wash frame. Sampling arrays will be disassembled, rinsed, and the animals/material from the samplers will be placed in 1-L plastic containers. Samples will be preserved with 10% buffered formalin and taken to the ESP laboratory for processing and identification.

A secondary sampling method may use towed plankton nets to collect drift samples. The collection of drifting macroinvertebrates will aid in the understanding of the overall riverine community and also will provide a list of taxa available for Hester-Dendy sampler colonization. Stations for these samples will be the same as described for artificial substrate samples. At each station, five replicate samples will be collected by towing a 0.5 m conical plankton net with 500 µm mesh in an upstream direction. Tows will be conducted for 3 minutes, and a flow meter will be installed in the net to measure the volume of water sampled during each replicate. Alternatively, if the river current is deemed sufficient in the field, the boat will be anchored in place and the plankton net deployed to the side or bow of the boat. After the tow is completed, the net will be retrieved and the organisms/material rinsed into a collection bucket. The sampled material will be transferred to 1-L plastic sample containers and preserved with 10% buffered formalin. Samples will be taken to MDNR's ESP laboratory for processing and identification of macroinvertebrate specimens.

Water Quality Sampling: Back wash from the softening basin will be the focus of water quality sampling for this study. Assessment of water quality will include *in situ* field measurements collected during each site visit, grab samples collected for laboratory analysis, as well as measurements collected using data sondes for the duration of the study. River velocity will be measured on the day grab samples are collected and the extent and shape of the plume will be noted. The duration of the back wash discharge also will be recorded. Field parameters will be collected using instruments calibrated and maintained according to applicable standard operating procedures and project procedures. These parameters will include temperature (MDNR-ESP-101), dissolved oxygen (MDNR-ESP-103), pH (MDNR-ESP-100), conductivity (MDNR-ESP-102), and turbidity (MDNR-ESP-012). Data sondes capable of collecting temperature, pH, conductivity, turbidity, and dissolved oxygen will be deployed in applicable locations for the duration of the study (i.e., during the macroinvertebrate colonization period of the multiple-plate samplers) according to MDNR-ESP-104.

Water quality grab samples will be collected once weekly during the Hester-Dendy sampling array deployment period for each of the three back wash types (pre-sedimentation, filter, and softening basin). Samples will be collected from the Missouri River within the blending reach downstream of the outfall, upstream of the outfall, and from the outfall itself. Samples will be analyzed for pH, TSS, TRC, and total dissolved metals by the Missouri Department of Natural Resources' Chemical Analysis Section in Jefferson City, Missouri. Samples will be collected, stored and transported according to procedures outlined in MDNR-ESP-001 (Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Sampling Considerations).

Study Timing: Multiple-plate samplers will be deployed in late summer or early fall for a duration of approximately 30 days. The exact study starting date will depend on when river conditions allow for sampling to be conducted safely.

Laboratory Methods: The samples of macroinvertebrates will be processed and identified per MDNR-ESP-209 (Taxonomic Levels for Macroinvertebrate Identification).

Data Recording and Analyses: Multiple-plate samplers will allow for the quantitative analysis of macroinvertebrate data. At each station, five replicate samples consisting of three Hester-Dendy units each will be analyzed for macroinvertebrate density, TR, and taxa composition. Statistical comparisons using Microsoft Excel software as well as Jandel Scientific software (SigmaStat) will be conducted to determine whether significant differences exist between the test and control stations.

A QSI for Taxa (QSI-T) also will be calculated to determine the percent similarity among test and control stations. QSI-T will be calculated using the following formula:

$$QSIT_{ab} = \sum \min(P_{ia}, P_{ib})$$

where P_{ia} = the relative abundance of species i at Station a,
P_{ib} = the relative abundance of species i at Station b, and
$\min(P_{ia}, P_{ib})$ = the minimum relative abundance of species i at Station a or b.

Values for this index range from 0-100%. Identical communities have a value of 100% and totally different communities have a value of 0%. In general, when comparing upstream/downstream samples (in this case, control vs. test stations), values less than 65% indicate environmental stress whereas values greater than 65% can occur as natural variation (Shackleford 1988).

Data Reporting: Results of the study will be summarized and interpreted in report format.

Quality Control: As stated in the various MDNR Project Procedures and Standard Operating Procedures.

Attachments: Map and aerial photo of study site, figures of sampling equipment.

References Cited

DeShon, J.E. Development and Application of the Invertebrate Community Index (ICI). pages 217-243 *in* W.S. Davis and T.P. Simon (editors). 1995. *Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making.* Lewis Publishers, Boca Raton, Florida.

Hester, E.F. and J.S. Dendy. 1962. A multiple-plate sampler for aquatic macroinvertebrates. Transactions of the American Fisheries Society 91(4): 420-421.

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Missouri Department of Natural Resources. 2012b. Field Analysis of Water Samples for pH. MDNR-ESP-100. Environmental Services Program. P.O. Box 176, Jefferson City, Missouri. 8 pp.

Missouri Department of Natural Resources. 2012c. Field Measurement of Water Temperature. MDNR-ESP-101. Environmental Services Program. P.O. Box 176, Jefferson City, Missouri. 3 pp.

Missouri Department of Natural Resources. 2012d. Sample Collection and Field Analysis of Dissolved Oxygen Using a Membrane Electrode Meter. MDNR-ESP-103. Environmental Services Program. P.O. Box 176, Jefferson City, Missouri. 16 pp.

Missouri Department of Natural Resources. 2012e. Taxonomic Levels for Macroinvertebrate Identifications. MDNR-ESP-209. Environmental Services Program, P.O. Box 176, Jefferson City, Missouri. 33 pp.

Shackleford, B. 1988. Rapid Bioassessment of Lotic Macroinvertebrate Communities. Arkansas Department of Pollution Control and Ecology. Little Rock, Arkansas. 44pp.

Figure 1. Map of Project Area

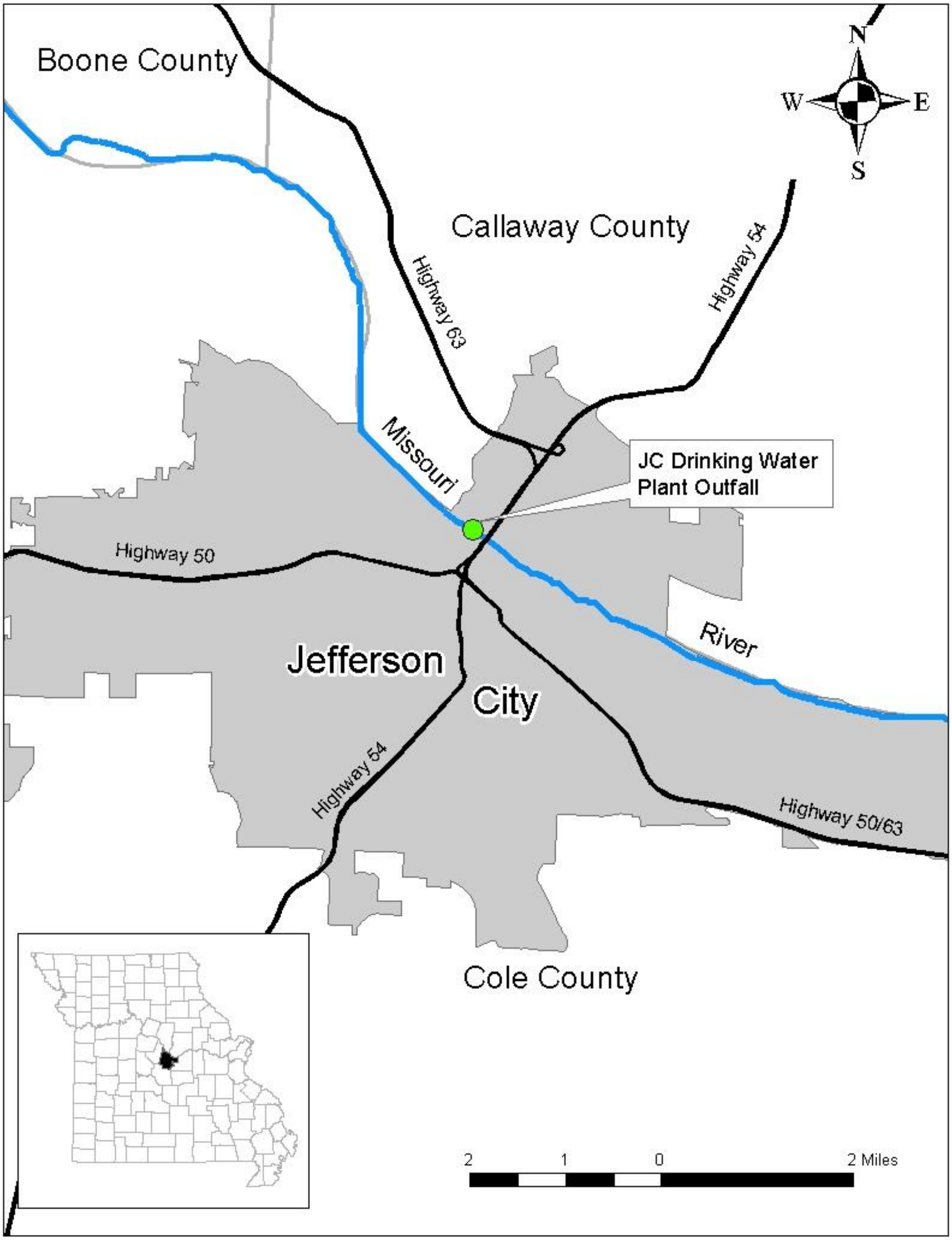
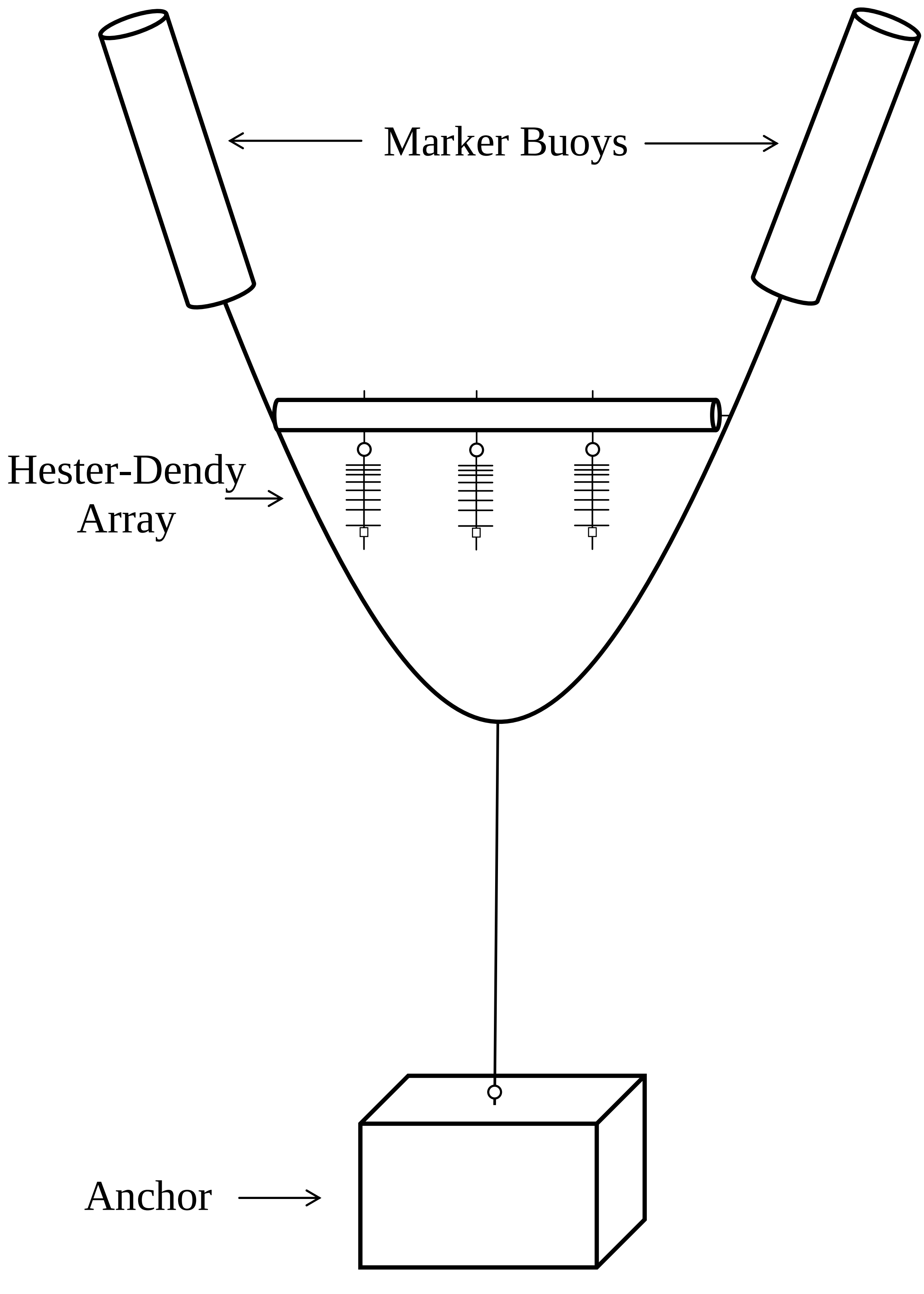


Figure 2. Aerial View of Jefferson City Drinking Water Treatment Plant

Figure 3. Example of multiple-plate sampling arrays.



Not to scale

Figure 4. 14-plate Hester-Dendy Sampler

Appendix C

Hester-Dendy and Rock Basket Macroinvertebrate Data Summary Tables

Hester-Dendy Station 1 (downstream)						
Replicate	Sample #	Subsample_N	TR	EPTT	BI	SDI
a	132032	583	31	16	5	2.27
b	132033	579	30	13	5.1	2.33
c	132034	731	27	14	4.8	2.08
d	132035	416	26	13	4.8	2.16
e	132036	1459	29	12	4.8	2.04
		Sum	avg TR	avg EPT	avg BI	avg SDI
		3768	28.6	13.6	4.9	2.176
		avg sub N				
		753.6				

Hester-Dendy Station 2 (outfall)						
Replicate	Sample #	Subsample_N	TR	EPTT	BI	SDI
a	132037	344	23	10	5.1	2.49
b	132038	150	23	9	5.2	2.31
c	132039	443	20	10	5.1	2.26
d	132040	540	27	14	4.9	2.29
e	132041	2051	28	16	4.9	1.87
		Sum	avg TR	avg EPT	avg BI	avg SDI
		3528	24.2	11.8	5.04	2.244
		avg sub N				
		705.6				

Hester-Dendy Station 3 (upstream control)						
Replicate	Sample #	Subsample_N	TR	EPTT	BI	SDI
a	132042	1418	21	10	5	1.6
b	132043	710	19	11	4.4	1.79
c	132044	lost				
d	132045	1582	12	9	4.3	1.36
e	132046	lost				
		Sum	avg TR	avg EPT	avg BI	avg SDI
		3710	17.33333	10	4.566667	1.583333
		avg sub N				
		1236.667				

Rock Basket Station 1 (downstream)						
Replicate	Sample #	Subsample_N	TR	EPTT	BI	SDI
a	132023	287	26	9	5.6	1.89
b	132024	839	27	12	5.1	1.96
c	132025	1485	25	10	4.8	1.67
		Sum	avg TR	avg EPT	avg BI	avg SDI
		2611	26	10.33333	5.166667	1.84
		avg sub N				
		870.3333				

Rock Basket Station 2 (outfall)						
Replicate	Sample #	Subsample_N	TR	EPTT	BI	SDI
a	132026	3	2	1	5.7	0.64
b	132027	112	23	12	5.4	2.37
c	132028	77	16	4	6.1	1.84
		Sum	avg TR	avg EPT	avg BI	avg SDI
		192	13.66667	5.666667	5.733333	1.616667
		avg sub N				
		64				

Rock Basket Station 3 (upstream control)						
Replicate	Sample #	Subsample_N	TR	EPTT	BI	SDI
a	132029	1598	26	9	4.6	1.78
b	132030	1971	28	10	5.1	1.76
c	132031	2032	25	11	4.8	1.68
		Sum	avg TR	avg EPT	avg BI	avg SDI
		5601	26.33333	10	4.833333	1.74
		avg sub N				
		1867				

Appendix D

Analysis of Variance and Kruskal-Wallis Analysis of Variance on Ranks and All Pairwise Means Comparisons among Stations for Rock Basket and Hester-Dendy Samples

(3=Control; 2=Outfall; 1=Downstream)

One Way Analysis of Variance Tuesday, March 04, 2014, 1:09:45 PM

Data source: MO RIVER 2013 DATA in Notebook 1 ROCK BASKETS.SNB

Dependent Variable: TOTAL INDIVIDUALS (25 percent subsample)

Normality Test: Passed (P = 0.243)

Equal Variance Test: Passed (P = 0.056)

Group Name	N	Missing	Mean	Std Dev	SEM
1.000	3	0	870.333	599.614	346.187
2.000	3	0	64.000	55.651	32.130
3.000	3	0	1867.000	234.949	135.648

Source of Variation	DF	SS	MS	F	P
Between Groups	2	4894326.889	2447163.444	17.570	0.003
Residual	6	835670.667	139278.444		
Total	8	5729997.556			

The differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.003).

Power of performed test with alpha = 0.050: 0.980

All Pairwise Multiple Comparison Procedures (Holm-Sidak method):
Overall significance level = 0.05

Comparisons for factor: **Station**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
3.000 vs. 2.000	1803.000	5.917	0.00104	0.017	Yes
3.000 vs. 1.000	996.667	3.271	0.0170	0.025	Yes
1.000 vs. 2.000	806.333	2.646	0.0382	0.050	Yes

One Way Analysis of Variance Tuesday, March 04, 2014, 1:18:02 PM

Data source: MO RIVER 2013 DATA in Notebook 1 ROCK BASKET.SNB

Dependent Variable: TR

Normality Test: Failed ($P < 0.050$)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks Tuesday, March 04, 2014, 1:18:02 PM

Data source: MO RIVER 2013 DATA in Notebook 1.SNB

Group	N	Missing	Median	25%	75%
1.000	3	0	26.000	25.250	26.750
2.000	3	0	16.000	5.500	21.250
3.000	3	0	26.000	25.250	27.500

H = 5.514 with 2 degrees of freedom. P(est.)= 0.063 P(exact)= 0.071

The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference ($P = 0.071$)

One Way Analysis of Variance Tuesday, March 04, 2014, 1:21:17 PM

Data source: MO RIVER 2013 DATA in Notebook 1 ROCK BASKETS.SNB

Dependent Variable: EPTT

Normality Test: Passed (P = 0.330)

Equal Variance Test: Passed (P = 0.205)

Group Name	**N**	**Missing**	**Mean**	**Std Dev**	**SEM**
1.000	3	0	10.333	1.528	0.882
2.000	3	0	5.667	5.686	3.283
3.000	3	0	10.000	1.000	0.577

Source of Variation	**DF**	**SS**	**MS**	**F**	**P**
Between Groups	2	40.667	20.333	1.710	0.258
Residual	6	71.333	11.889		
Total	8	112.000			

The differences in the mean values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.258).

Power of performed test with alpha = 0.050: 0.121

The power of the performed test (0.121) is below the desired power of 0.800.
Less than desired power indicates you are less likely to detect a difference when one actually exists. Negative results should be interpreted cautiously.

One Way Analysis of Variance Tuesday, March 04, 2014, 2:27:41 PM

Data source: MO RIVER 2013 DATA in Notebook 1 ROCK BASKETS.SNB

Dependent Variable: BI

Normality Test: Passed (P = 0.316)

Equal Variance Test: Passed (P = 0.422)

Group Name	**N**	**Missing**	**Mean**	**Std Dev**	**SEM**
1.000	3	0	5.167	0.404	0.233
2.000	3	0	5.733	0.351	0.203
3.000	3	0	4.833	0.252	0.145

Source of Variation	**DF**	**SS**	**MS**	**F**	**P**
Between Groups	2	1.242	0.621	5.324	0.047
Residual	6	0.700	0.117		
Total	8	1.942			

The differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.047).

Power of performed test with alpha = 0.050: 0.515

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparisons for factor: **Station**

Comparison	**Diff of Means**	**p**	**q**	**P**	**P<0.050**
2.000 vs. 3.000	0.900	3	4.564	0.041	Yes
2.000 vs. 1.000	0.567	3	2.874	0.185	No
1.000 vs. 3.000	0.333	3	1.690	0.498	No

One Way Analysis of Variance Tuesday, March 04, 2014, 1:42:17 PM

Data source: MO RIVER 2013 DATA in Notebook 1 ROCK BASKETS.SNB

Dependent Variable: SDI

Normality Test: Passed (P = 0.077)

Equal Variance Test: Passed (P = 0.133)

Group Name	N	Missing	Mean	Std Dev	SEM
1.000	3	0	1.840	0.151	0.0874
2.000	3	0	1.627	0.890	0.514
3.000	3	0	1.740	0.0529	0.0306

Source of Variation	DF	SS	MS	F	P
Between Groups	2	0.0684	0.0342	0.125	0.884
Residual	6	1.637	0.273		
Total	8	1.705			

The differences in the mean values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.884).

Power of performed test with alpha = 0.050: 0.050

The power of the performed test (0.050) is below the desired power of 0.800.
Less than desired power indicates you are less likely to detect a difference when one actually exists. Negative results should be interpreted cautiously.

One Way Analysis of Variance Friday, July 25, 2014, 6:54:17 AM

Data source: MO RIVER 2013 DATA in Hester-Dendy 2013.SNB

Dependent Variable: Total Individuals (25 percent subsample)

Normality Test: Passed (P = 0.067)

Equal Variance Test: Passed (P = 0.852)

Group Name	N	Missing	Mean	Std Dev	SEM
1.000	5	0	753.600	409.775	183.257
2.000	5	0	705.600	765.821	342.486
3.000	3	0	1236.667	463.419	267.555

Source of Variation	DF	SS	MS	F	P
Between Groups	2	599106.010	299553.005	0.869	0.449
Residual	10	3447107.067	344710.707		
Total	12	4046213.077			

The differences in the mean values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.449).

Power of performed test with alpha = 0.050: 0.049

The power of the performed test (0.049) is below the desired power of 0.800.
Less than desired power indicates you are less likely to detect a difference when one actually exists. Negative results should be interpreted cautiously.

One Way Analysis of Variance Friday, July 25, 2014, 6:49:08 AM

Data source: MO RIVER 2013 DATA in Hester-Dendy.SNB

Dependent Variable: Density (individuals per sq. ft.)

Normality Test: Passed (P = 0.068)

Equal Variance Test: Passed (P = 0.852)

Group Name	N	Missing	Mean	Std Dev	SEM
1.000	5	0	1004.400	546.405	244.360
2.000	5	0	940.400	1020.938	456.577
3.000	3	0	1648.333	618.016	356.812

Source of Variation	DF	SS	MS	F	P
Between Groups	2	1064592.010	532296.005	0.869	0.449
Residual	10	6127381.067	612738.107		
Total	12	7191973.077			

The differences in the mean values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.449).

Power of performed test with alpha = 0.050: 0.049

The power of the performed test (0.049) is below the desired power of 0.800.
Less than desired power indicates you are less likely to detect a difference when one actually exists. Negative results should be interpreted cautiously.

One Way Analysis of Variance Tuesday, March 04, 2014, 1:19:31 PM

Data source: MO RIVER 2013 DATA in Notebook 1 HESTER DENDY.SNB

Dependent Variable: TR

Normality Test: Passed (P = 0.702)

Equal Variance Test: Passed (P = 0.215)

Group Name	N	Missing	Mean	Std Dev	SEM
1.000	5	0	28.600	2.074	0.927
2.000	5	0	24.200	3.271	1.463
3.000	3	0	17.333	4.726	2.728

Source of Variation	DF	SS	MS	F	P
Between Groups	2	238.103	119.051	11.374	0.003
Residual	10	104.667	10.467		
Total	12	342.769			

The differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.003).

Power of performed test with alpha = 0.050: 0.950

All Pairwise Multiple Comparison Procedures (Holm-Sidak method):
Overall significance level = 0.05

Comparisons for factor: **Station**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
1.000 vs. 3.000	11.267	4.769	0.000759	0.017	Yes
2.000 vs. 3.000	6.867	2.906	0.0157	0.025	Yes
1.000 vs. 2.000	4.400	2.150	0.0570	0.050	No

One Way Analysis of Variance Tuesday, March 04, 2014, 1:22:15 PM

Data source: MO RIVER 2013 DATA in Notebook 1 HESTER DENDY.SNB

Dependent Variable: EPTT

Normality Test: Passed (P = 0.562)

Equal Variance Test: Passed (P = 0.280)

Group Name	N	Missing	Mean	Std Dev	SEM
1.000	5	0	13.600	1.517	0.678
2.000	5	0	11.800	3.033	1.356
3.000	3	0	10.000	1.000	0.577

Source of Variation	DF	SS	MS	F	P
Between Groups	2	24.923	12.462	2.596	0.124
Residual	10	48.000	4.800		
Total	12	72.923			

The differences in the mean values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.124).

Power of performed test with alpha = 0.050: 0.255

The power of the performed test (0.255) is below the desired power of 0.800.
Less than desired power indicates you are less likely to detect a difference when one actually exists. Negative results should be interpreted cautiously.

One Way Analysis of Variance Tuesday, March 04, 2014, 2:29:39 PM

Data source: MO RIVER 2013 DATA in Notebook 1 HESTER DENDY.SNB

Dependent Variable: BI

Normality Test: Passed (P = 0.079)

Equal Variance Test: Passed (P = 0.595)

Group Name	N	Missing	Mean	Std Dev	SEM
1.000	5	0	4.900	0.141	0.0632
2.000	5	0	5.040	0.134	0.0600
3.000	3	0	4.567	0.379	0.219

Source of Variation	DF	SS	MS	F	P
Between Groups	2	0.424	0.212	4.838	0.034
Residual	10	0.439	0.0439		
Total	12	0.863			

The differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.034).

Power of performed test with alpha = 0.050: 0.554

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparisons for factor: **Station**

Comparison	Diff of Means	p	q	P	P<0.050
2.000 vs. 3.000	0.473	3	4.376	0.028	Yes
2.000 vs. 1.000	0.140	3	1.495	0.560	No
1.000 vs. 3.000	0.333	3	3.082	0.123	No

One Way Analysis of Variance Tuesday, March 04, 2014, 1:44:13 PM

Data source: MO RIVER 2013 DATA in Notebook 1 HESTER DENDY.SNB

Dependent Variable: SDI

Normality Test: Passed (P = 0.455)

Equal Variance Test: Passed (P = 0.686)

Group Name	**N**	**Missing**	**Mean**	**Std Dev**	**SEM**
1.000	5	0	2.176	0.123	0.0550
2.000	5	0	2.244	0.228	0.102
3.000	3	0	1.583	0.215	0.124

Source of Variation	**DF**	**SS**	**MS**	**F**	**P**
Between Groups	2	0.918	0.459	12.730	0.002
Residual	10	0.361	0.0361		
Total	12	1.278			

The differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.002).

Power of performed test with alpha = 0.050: 0.971

All Pairwise Multiple Comparison Procedures (Holm-Sidak method):
Overall significance level = 0.05

Comparisons for factor: **Station**

Comparison	**Diff of Means**	**t**	**Unadjusted P**	**Critical Level**	**Significant?**
2.000 vs. 3.000	0.661	4.765	0.000763	0.017	Yes
1.000 vs. 3.000	0.593	4.274	0.00163	0.025	Yes
2.000 vs. 1.000	0.0680	0.566	0.584	0.050	No

One Way Analysis of Variance Wednesday, March 05, 2014, 2:32:05 PM

Data source: MO RIVER 2013 DATA in MO RIVER 2013 HESTER DENDY.SNB

Dependent Variable: TR/sq.ft

Normality Test: Passed (P = 0.700)

Equal Variance Test: Passed (P = 0.196)

Group Name	**N**	**Missing**	**Mean**	**Std Dev**	**SEM**
1.000	5	0	9.540	0.673	0.301
2.000	5	0	8.080	1.064	0.476
3.000	3	0	5.767	1.570	0.906

Source of Variation	**DF**	**SS**	**MS**	**F**	**P**
Between Groups	2	26.703	13.351	11.850	0.002
Residual	10	11.267	1.127		
Total	12	37.969			

The differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.002).

Power of performed test with alpha = 0.050: 0.959

All Pairwise Multiple Comparison Procedures (Holm-Sidak method):
Overall significance level = 0.05

Comparisons for factor: **Station**

Comparison	**Diff of Means**	**t**	**Unadjusted P**	**Critical Level**	**Significant?**
1.000 vs. 3.000	3.773	4.868	0.000654	0.017	Yes
2.000 vs. 3.000	2.313	2.984	0.0137	0.025	Yes
1.000 vs. 2.000	1.460	2.175	0.0547	0.050	No

One Way Analysis of Variance Wednesday, March 05, 2014, 2:01:30 PM

Data source: MO RIVER 2013 DATA in MO RIVER 2013 HESTER DENDY.SNB

Dependent Variable: EPTT/sq.ft

Normality Test: Passed (P = 0.476)

Equal Variance Test: Passed (P = 0.295)

Group Name	N	Missing	Mean	Std Dev	SEM
1.000	5	0	4.520	0.502	0.224
2.000	5	0	3.920	1.016	0.454
3.000	3	0	3.333	0.351	0.203

Source of Variation	DF	SS	MS	F	P
Between Groups	2	2.714	1.357	2.521	0.130
Residual	10	5.383	0.538		
Total	12	8.097			

The differences in the mean values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.130).

Power of performed test with alpha = 0.050: 0.244

The power of the performed test (0.244) is below the desired power of 0.800.
Less than desired power indicates you are less likely to detect a difference when one actually exists. Negative results should be interpreted cautiously.